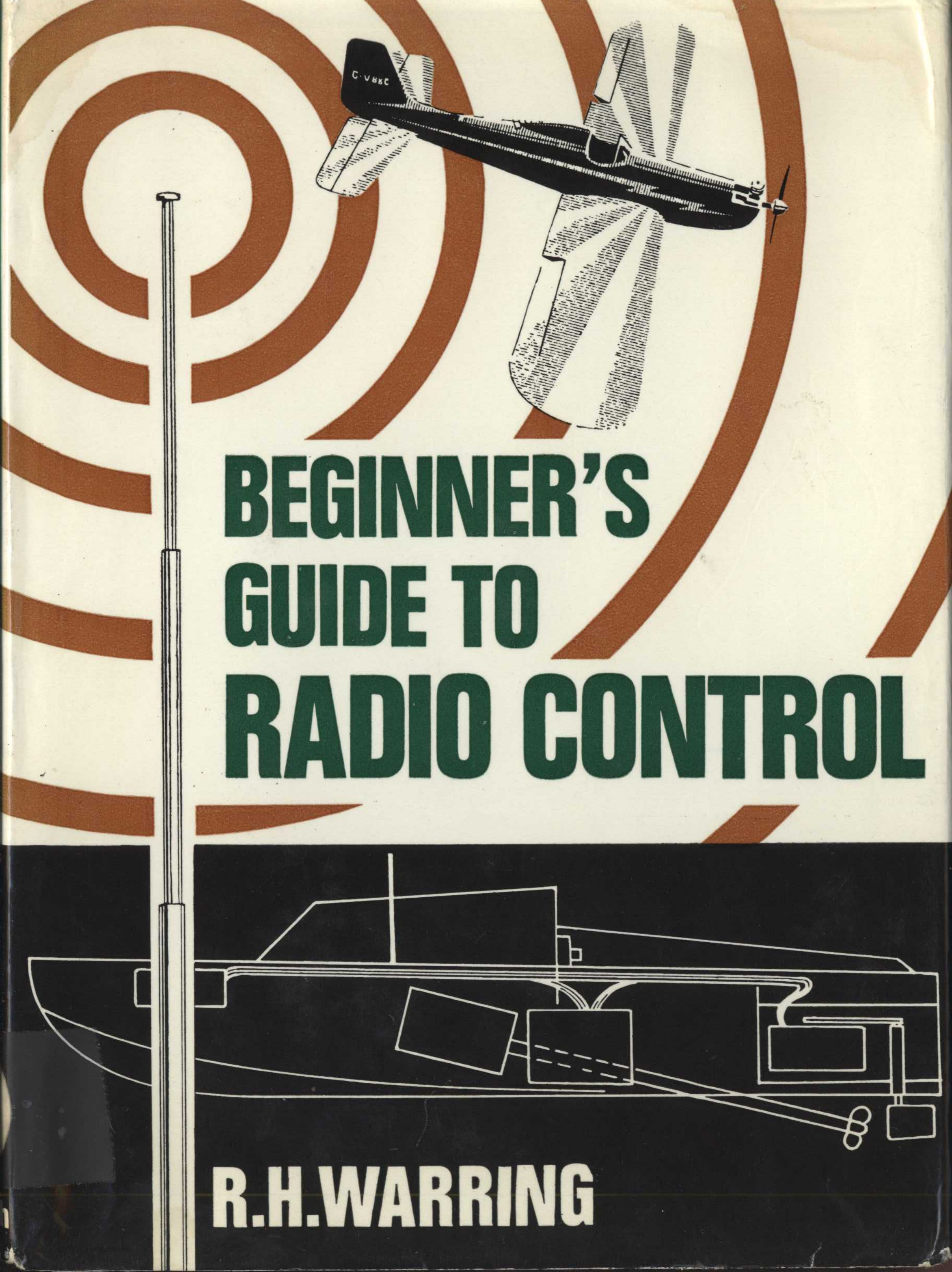

BEGINNER'S GUIDE TO RADIO CONTROL

R.H.WARRING

This is the ideal book for the model builder who wishes to understand the elements of radio control operation; how to install it, how to make the most practical use of it and how it works.

This is not a guide to making a radio control unit itself but a guide to the operation of ready-made units. There are tables at the end of each chapter which give the relative prices and requirements for any given set-up.

The merits of the different systems are discussed and advice given on the best practical arrangement. Complete instructions are given for making all the manoeuvres and aerobatics that the modeller is likely to want—whether it is the simplest design or the most complex multi-channel operation.

As in R. H. Warring's previous books on hobbies for beginners, this book assumes that the reader knows nothing of radio control operation, but Mr. Warring's enthusiasm for his hobby is catching, and those who start to read it with modest plans for their model are sure to finish with more ambitious ideas and a complete understanding of the subject.

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BEGINNER'S GUIDE TO RADIO CONTROL

BEGINNER'S GUIDE TO RADIO CONTROL

Written and illustrated by
R. H. WARRING

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CHAPTER 1

DEVELOPMENT OF RADIO CONTROL

THE foundations for the practical application of radio signals for the remote control of models were laid some thirty years ago, but it is only comparatively recently that working radio control systems have become sufficiently reliable for them to be suitable for general use, i.e. by people who are essentially modellers and not necessarily experienced in radio technology. Today one needs no knowledge at all of radio to install and operate radio control systems successfully, only an appreciation of the practical problems involved. In fact, the more complex the electronic circuitry involved, often the simpler it is to install and operate since all the electronic units may be pre-wired, as supplied by the manufacturers, and merely need plugging together. This is the modern idea of the "black box" conception in electronic engineering. It is not necessary to know *how* the "black box" works, merely what it *does*. If anything goes wrong internally, then the "black box" has to be returned to a specialist to diagnose the fault and correct it.

This is a far cry from the early days of radio control when there was no commercially produced equipment and every radio control modeller had to be something of a radio expert, for he had to build his own sets, and often design the circuits as well. The great disadvantage of this was that it limited participation in radio control modelling to a handful of enthusiasts, most of whom were far more expert at radio than modelling. As a result the radio systems which evolved as workable and formed the basis of the earliest commercial equipment did not necessarily cover the practical needs of a good working system for model control. Also all this early work was carried out in the days before the transistor so that, forced to use valve circuits, radio receivers tended to be bulky and heavy and demanded the use of heavy batteries.

Nevertheless there was quite considerable progress. In America, a radio control event for model aircraft was held annually from as early as 1936, until temporarily stopped by America's entry into the war. The lessons learnt were incorporated in commercially produced equipment, available again in the later 1940s, which provided the modeller without previous radio knowledge with a basis for starting on his own. Also the development of the sub-miniature thyratron valve permitted a certain degree of miniaturization to be attempted with radio control receivers.

At this stage it was possible for the modeller to buy commercial equipment and get reasonable working results by following basic instructions for wiring up and tuning, etc. Performance was, however, far from consistent and the most successful results were obtained by modellers with a knowledge of radio, or the radio enthusiast turning to modelling as a means of utilizing his equipment.

Neither combination was particularly successful. The first-class modeller was usually deficient in radio knowledge; and the radio enthusiast deficient in modelling prowess or knowledge of the limitations in applying basic control systems to working models. As a result the modeller tended to become frustrated with the limitations of available radio equipment and his own inability to rectify basic limitations; and the radio technician tended to put into production equipment which was not fully proven and did not perform in a model as it did on the test bench.

At the same time, interest in radio control and demand for suitable equipment continued to grow, this coming primarily from modellers. Virtually anyone who could produce radio control equipment which worked, after a fashion, could be assured of sales at this stage because the technology involved was beyond that of the average modeller. Because of the considerable demand the incentive was to rush designs into production before they were proven and the resulting considerable proportion of unsatisfactory commercial equipment which did appear, as a consequence, harmed the general interest as it only underlined the distinct limitations of simple radio control systems. The more sophisticated systems suffered even more. Expensive to produce, and promising much more, the then current productions were all too often unsuitable as practical radio control units.

However, amongst the post-war pioneers were modellers who also had a flair for electronics and mastered the basic technology involved; and radio enthusiasts with the ability to become first-class modellers and think in terms of model requirements. Either combination is rare, and hence they were relatively few in number. Their success, however, was such as to establish new standards for requirements for radio control unit design and production. Once these standards had been reached and the customer could judge by results achieved, less satisfactory equipment automatically began to disappear from the market.

This marked the era of the appearance of really reliable radio control equipment, embracing first the simpler single-channel systems, from which stemmed the far more useful—but more costly—multi-channel systems. It was also significant that virtually all the leading equipment was produced on an identical basis, and with very similar (and in some cases virtually identical) transmitter and receiver circuit design.

At the same time there was still scope for further development and different methods of approach, many of which was made attractive by lower cost or better availability (virtually the whole of the "new standard" development originating in the United States). None offered similar performance and reliability, however, except for developments improving the new standards. A considerable impetus in this respect was given by the availability of transistors of suitable type, and at reasonable cost. Directly, this meant that receivers, in particular, could be reduced in bulk and weight and the voltage requirements of the batteries reduced.

Transistors offered the immediate prospect of miniaturization and, as more types became available capable of improved performance, of improved circuit design. Transistors are, basically, amplifiers and their first main application was for boosting minute signals in the receiver circuit to higher levels for more reliable operation. This led directly to the relayless receiver where the receiver current change is amplified to such an extent that it can be applied directly as an output to operate an actuator. Previously receiver current levels were only sufficient to operate a sensitive relay, the contact of which acted as an "on/off" switch controlling a separate battery supply to the actuator. Besides eliminating the weight and bulk of the relay and second battery, the relayless receiver also eliminated another source of inconsistency—the possibility of poor switching action due to relay contacts being dirty or burnt and the susceptibility of the relay to false switching if affected by vibration.

The all-transistor receiver came later, simply because originally there was no suitable transistor available to take the place of a miniature valve as a detector of the radio signal. Also the standard form of circuit, based on a valve detector with transistors in the following stages provided such reliable performance, both in relay and relayless receiver version, that it could not be improved upon for consistency.

However, when suitable transistors did become available the all-transistor receiver eventually became the standard because of the greater degree of miniaturization possible, plus the fact that the whole receiver could then be worked off a single low-voltage battery. Between the transition there were plenty of all-transistor receivers produced which offered the advantage of reduced size and weight and a single battery supply, but compared most unfavourably in actual performance.

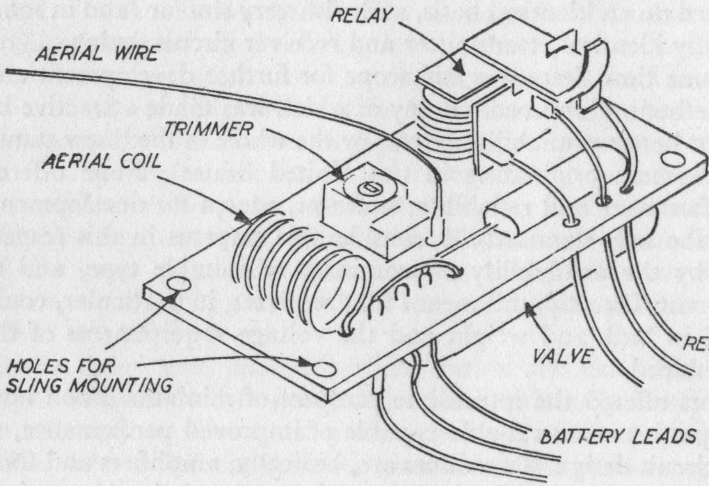


Fig. 1.1.

Another change which produced a marked improvement in reliability was the use of "tone" rather than "carrier" signalling. The simplest form of signal is a radio wave of the required frequency—usually 27 million cycles (megacycles) per second in the case of radio control sets—Fig. 1.2. This can be interpreted by the receiver circuit to cause a change in current in the receiver, this change being used to produce a response in the receiver—e.g. operate a relay.

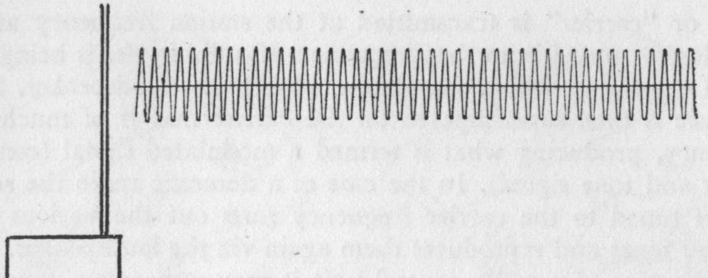


Fig. 1.2.

An alternative method is to transmit this basic radio signal continuously, which usually has the effect of producing a steady but very low current flow through the receiver circuit, when tuned in to the basic signal. For actually operating the receiver, however—which really means making the control signal produce a change in current flowing through the receiver circuit—a separate lower-frequency or "tone" signal is superimposed on the basic or "carrier" signal to produce a tone-modulated waveform—Fig. 1.3.

This, in fact, is the way a broadcast transmission works. The basic

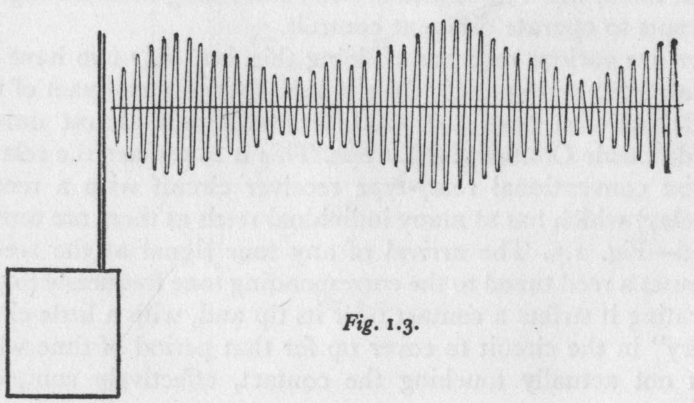


Fig. 1.3.

signal or "carrier" is transmitted at the station frequency and the receiving set tuned in to that frequency. If nothing else is being transmitted the carrier will be heard as a "hiss" in the loudspeaker. Speech or music is then superimposed on the carrier and is of much lower frequency, producing what is termed a modulated signal (combined carrier and tone signal). In the case of a domestic radio the receiver circuits tuned to the carrier frequency sorts out the various superimposed tones and reproduces them again via the loudspeaker.

In the case of a radio control unit it may appear an unnecessary complication to use a tone signal to modulate the carrier for a simple "on/off" control system as the receiver merely decodes the tone signal in a similar manner to what it would do with a carrier signal simply switched on and off. There are, however, certain technical advantages, such as better sensitivity and range, offered by tone signalling. Although it does involve more components and a slightly more complicated circuit, it is the better system. For this reason "carrier wave" or "carrier only" single-channel transmitter–receiver combinations have gradually died out in favour of tone transmitter-receiver combinations.

Where more than one control signal is required, then "tone" signalling is an obvious solution. It is simple enough to arrange this at the transmitter end. Separate switches are arranged to switch on or off separate tone circuits linked to the basic (carrier) circuit to impose separate tones as and when keyed—Fig. 1.4. The main complication then comes at the receiver end—providing a means of decoding the different tones, when transmitted, and channelling these through separate outputs to operate different controls.

There are various methods of doing this, but only two have proved practical. Strangely enough, the simplest and most compact of the two methods has also been the most successful and almost universally adopted outside Continental Europe. This is to replace the relay in an otherwise conventional relay-type receiver circuit with a reed bank (reed relay) which has as many individual reeds as there are tones to be decoded—Fig. 1.5. The arrival of any tone signal at the reed bank then causes a reed tuned to the corresponding tone frequency to vibrate. In vibrating it strikes a contact near its tip and, with a little electronic "trickery" in the circuit to cover up for that period of time when the reed is not actually touching the contact, effectively completes an

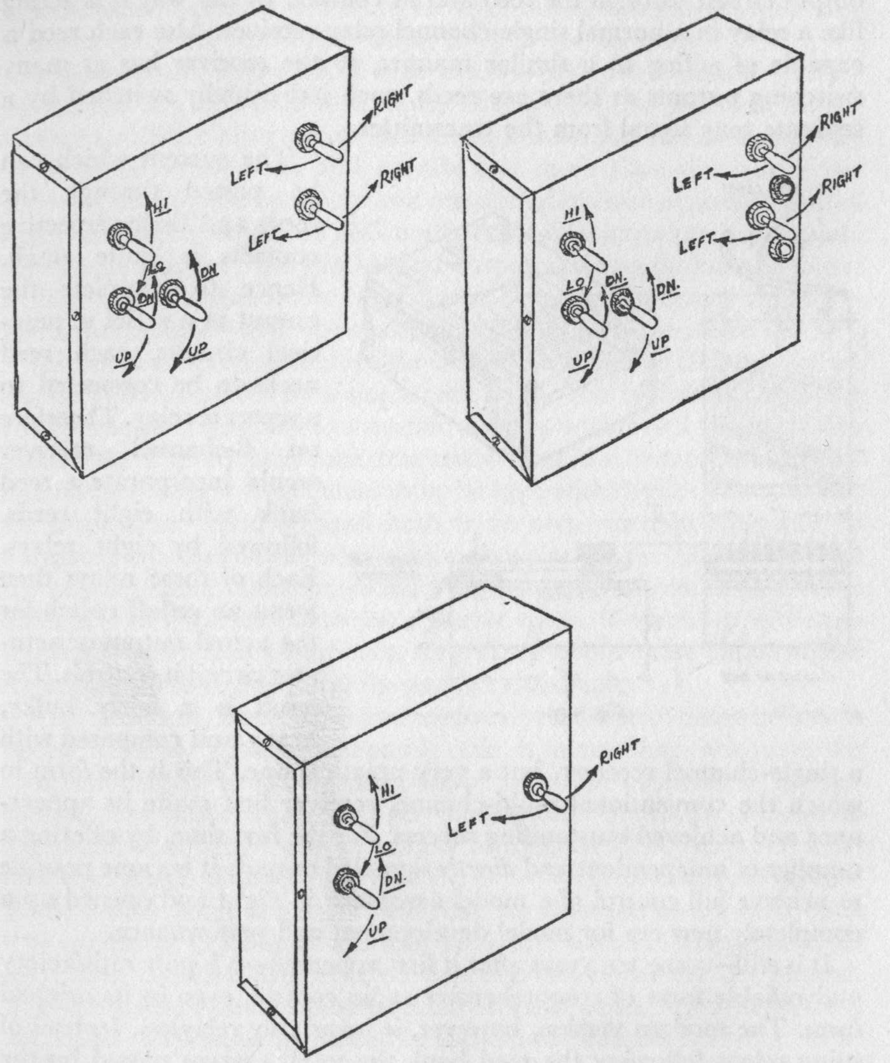


Fig. 1.4.

output circuit through the reed and its contact. In this way it is acting like a relay in a normal single-channel relay receiver. Also each reed is capable of acting in a similar manner, so the receiver has as many switching outputs as there are reeds, each individually switched by a separate tone signal from the transmitter.

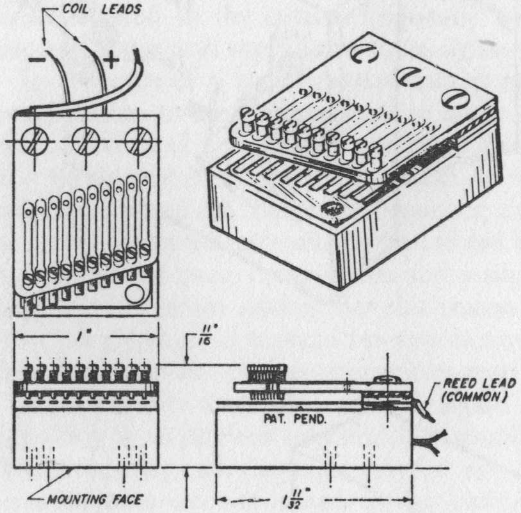


Fig. 1.5.

The current which can be passed through the reeds and their respective contacts is quite small. Hence to complete the output as a series of practical circuits, each reed needs to be connected to a separate relay. Therefore an 8-channel receiver would incorporate a reed bank with eight reeds, followed by eight relays. Each of these relays then forms an on/off switch for the actual output or actuator circuit it controls. The result is a fairly bulky, heavy unit compared with a single-channel receiver, but a very practical one. This is the form in which the conventional multi-channel receiver first made its appearance and achieved outstanding success. For the first time, by offering a number of independent and *directly* signalled outputs it became possible to achieve full control of a model aeroplane in flight and opened up a completely new era for model development and performance.

It is still—some ten years after it first appeared—a highly satisfactory and reliable form of comprehensive radio control, even in its original form. The modern version, however, is invariably relayless. Instead of using relays following the reed bank the small current passed by the individual reeds on command is amplified by special transistor circuits to operate an actuator direct. These transistor amplifiers are normally built into the actuators themselves, thus reducing the bulk of the actual

multi-channel receiver to little more than that of a single-channel relay receiver (with the reed bank taking the place of the relay).

The successful operation of such a receiver depends almost entirely on the use of a first-class reed bank. This is a job for precision manufacture and there are no short cuts as regards simplification or expense. Thus a good reed bank will usually cost more than the rest of the receiver, making the complete unit considerably more expensive than a single-channel receiver. It also needs expensive actuators to translate the circuit response into mechanical output, once again manufactured to high precision standards. Overall cost, therefore, increases directly—and substantially—with the number of channels to be utilized.

In practice there is a limit to the number of separate channels which can be accommodated by a single reed bank. The individual reeds are cut to resonant lengths—i.e. specific lengths which will vibrate when excited by a particular tone frequency—but the complete range of individual resonant frequencies must be kept within one octave. If not, the same reed would respond both to its own resonant tone and its harmonic signalled in the next octave above or below. Also the greater the number of individual frequencies crowded into an octave the less the difference in frequency between adjacent reeds. If carried to extremes this could mean that a particular tone signal could cause its particular resonant reed to vibrate, and the ones on either side.

The practical limit with conventional reed-bank construction is twelve separate reeds. Fortunately this is more than adequate for complete control of any working model; and ten channels is, in fact, enough. For model controls other than aircraft a smaller number of individual control services are usually satisfactory. Thus multi-channel reed equipment is usually made in 6-, 8-, 10- and 12-channel versions. There is little point in going to less than six channels as a 3-reed bank is as expensive to make as a 6-reed bank and with far less demand. If only three channels are required then the others can be left unused. This is a useful point to bear in mind when selecting equipment for a particular purpose, as explained in subsequent chapters.

The alternative to using an electro-mechanical device (i.e. a reed bank) as a means of sorting out individual tones is electronic filter circuits embodied in the receiver design. These can be spread over a much wider tone range than a reed bank can handle, and can also be made far less susceptible to inter-channel interference. This does, however, result in a much more complicated and costly receiver. The chief advantage is the complete elimination of contacts from the circuit which could get out of adjustment in a crash, or become dirty; although strangely enough the bulk of commercial multi-channel receivers produced to date on this basis follow the electronic filter stages with relays for final switching output, this has been done largely to offset the higher receiver cost by eliminating the further cost of transistor amplifiers associated with the actuators.

Most of the commercially produced tone-filter receivers are supplied as pre-tuned units matched to a particular transmitter. The only adjustment available to the user is receiver tuning (i.e. to the basic carrier signal), and even then not invariably so. A successful design of tone-filter receiver must, therefore, be extremely stable so that it is unaffected by temperature or other changes which could result in the decoding circuits going "off tune". Being all-electronic, such receivers do have certain advantages, however, and may also be used for single-channel equipment as well as "multi".

All of the equipment so far described is based on the simplest possible type of basic receiver circuit capable of giving the range and performance necessary, known technically as a superregenerative circuit. Every receiver circuit must, essentially, provide a compromise between sensitivity and selectivity. *Sensitivity* is the actual response to signal, the greater the sensitivity the greater the operating range with a given transmitter signal strength. *Selectivity* is the ability to tune in to a signal of specific frequency and reject spurious signals of near-by frequency. The two are interrelated as adjusting the sensitivity will usually affect the selectivity. Also the superregen. circuit is somewhat critical in operation and an increase in sensitivity may bring the working point down to the point of instability in the circuit.

Originally all receivers used to have both sensitivity and selectivity controls, needing adjustment by the operator for best results. Also because of circuit stability limitations, readjustment from time to time—and in some cases every time before use—was necessary. One of the greatest advances has been the development of more stable circuits which can be adjusted by a single tuning control only and, once properly adjusted, normally need no further attention other than

a periodic check that tuning is at an optimum position. This was the first step in bringing model radio control units into the "black box" era.

Nevertheless it remains a characteristic of all superregen. receivers that their selectivity is fairly broad. This means that although tuned to a specific transmitter signal frequency they will tend to pick up spurious signals from other sources of near-by frequency. Thus it is virtually impossible to operate two superregen. receivers simultaneously (unless of special design), each controlled by their separate transmitters, even if they are operating at different ends of the permitted frequency range (see Chapter 2). The "wrong" transmitter will always affect the other receiver. Also if the two receivers are fairly close to each other, one receiver can even interfere with the other merely by being switched on.

This represents a very real operating problem, for it limits the operation of radio-controlled models to one at a time in a particular area; and there is also always the chance of picking up other spurious signals in the 27 megacycle band to interfere with operation. Some industrial electronic equipment generates signals of this frequency, for example, also hospital, scientific and commercial equipment.

Imported (Japanese) "walkie-talkie" radio sets operate right in the 27 megacycle band (usually at 27·12 megacycles/second) and although they only have limited range—from about one quarter of a mile to two or three miles, depending on type—they can prove a source of considerable trouble to radio model operators. The use of these sets in this country is illegal, but that does not stop them being sold in considerable quantities, and obviously used by the purchasers!

There is no real answer to this with a superregen. receiver. To overcome it it is necessary to go to a considerably more complicated receiver design, the superheterodyne or "superhet.". This type of circuit provides extreme selectivity and needs to be matched to a specific receiver by means of a pair of crystals. One crystal is fitted into the transmitter circuit and controls the frequency of the transmitter (carrier) signal to an exact or "spot" frequency. The matching crystal (normally of lower frequency, differing by the intermediate frequency of the superhet. circuit) is fitted into the receiver circuit.

So precise is the selectivity of such a receiver that it will be unaffected by other signals quite close to those of its own matched transmitter frequency (crystal "spot" frequency) and a considerable number of transmitter–receiver combinations can be operated simultaneously, provided each is working on a different "spot" frequency. Specific spot frequencies totalling thirteen in all are allocated within the permitted 27 megacycle band, to which all but a few Continental manufacturers conform (see Table 1).

Table 1

"SPOT" FREQUENCIES

Spot	*Frequency megacycles/sec*	*Colour code**
0	26·970	black
1	26·995	brown
2	27·020	brown/red
3	27·045	red
4	27·070	red/orange
5	27·095	orange
6	27·120	orange/yellow
7	27·145	yellow
8	27·170	yellow/green
9	27·195	green
10	27·220	green/blue
11	27·245	blue
12	27·270	white

* This colour code may be used to identify crystals. Its main intention, however, is to identify the "spot" frequency at which a transmitter is being operated, a flag or pennant of this colour being attached to the aerial.

Apart from cost (and slightly increased bulk), the only disadvantage of the superhet. receiver is that it cannot be adjusted simply by tuning but needs *alignment* of the circuit, which really calls for the use of an oscilloscope. As a consequence superhet. receivers are normally true "black box" units, supplied prealigned and requiring no adjustment whatsoever on the part of the operator. This, of course, is really an advantage rather than a disadvantage, except that in the case of unsatisfactory working the only recourse is to return the unit to the manufacturer or service agent for checking.

The superhet. is particularly advantageous for multi-channel outfits, if only for the additional safeguard provided against interference and possible damage resulting in a crash to quite expensive equipment. It is probably even more advantageous with single-channel receivers, which are more numerous in number, and thus even more likely to be interfered with accidentally by other operators. However, since the main attraction of a single-channel is minimum cost, the cheaper superregen. receiver still remains the most popular commercial type.

Ultimate development, as far as conventional model radio control is concerned, is fully proportional control. With conventional single-channel and multi-channel working, control operation is on a "full on" or "full off" basis—e.g. in the case of a rudder this would mean full right (or left) when signalled "on"; and neutral position with signal "off". Proportional control means that the movement can be to any position between neutral and full on in exact proportion to the amount of control movement signalled at the transmitter end—e.g. by movement of a control stick. This is the same sort of control produced by a pilot in a full-size aircraft and obviously offers more realistic and more complete control.

Proportional control systems are by no means new. In fact, proportional controls were being developed and worked before conventional multi-channel appeared, but they had very many limitations in the early days, both electronic and mechanical, to the extent that they were virtually unworkable except on the test bench. Conventional multi-channel, when it appeared, offered so much more positive control. It was not until 1963–65 that proportional systems really appeared as successful commercial units which could be installed as "black box" equipment by modellers. Prior to that the only success achieved with proportional control systems was restricted to a relatively small number of individual experts capable of both designing and building their own equipment.

Today, anyone with a reasonable experience of practical modelling can buy, install and successfully operate proportional control systems without needing any knowledge of electronics. Although the circuitry is far more sophisticated than conventional multi-channel, equipment is completely pre-set and pre-adjusted, using superhet. receivers and plug-together circuitry. The one serious objection is their cost and the price of a complete outfit can run as high as £500, with £150–£200 currently about the minimum for complete control coverage. Also they still have certain snags needing to be ironed out before they can be accepted as a "complete" answer.

Nevertheless, there is a place for all three basic systems—single-channel for minimum-cost radio control; conventional multi-channel for complete *functional* control requirements; and fully proportional systems for precise, infinitely variable control for the ultimate in performance, and where cost is not a main consideration. There are also a number of "intermediate" systems which aim to overcome the control limitations of single-channel systems without running into the cost of more elaborate transmitter–receiver combinations.

Special note:

A G.P.O. licence is required for the operation of radio control equipment. This can be obtained on application to:

Radio Branch, Radio and Accommodations Department, G.P.O.
Headquarters, London E.C.1.

The cost of this licence is 20/-, covering a period of five years.

CHAPTER 2

TYPES AND SCOPE OF RADIO CONTROL EQUIPMENT

THE basic types of radio control which have evolved as practical equipment have been described in Chapter 1. To understand how they work and their scope and application it is necessary to describe them in more detail under separate headings as they fall into quite distinct classes. All, however, have a similar underlying principle of working and it is necessary that this should be understood first.

Any radio-control link demands the use of a transmitter and a matching receiver. By "matching" is really meant a receiver which can be tuned to the transmitter signal frequency and respond to the type of signal put out by the transmitter, e.g. whether the signal is simply a carrier wave or a tone-modulated carrier.

In some cases the "matching" may be specific. Thus the superhet. receiver can be matched to a suitable transmitter only via a matched pair of crystals (one in the transmitter circuit and one in the receiver circuit). On the other hand, any superrregen. carrier-type receiver can be tuned to any carrier transmitter. Apart from having broad tuning characteristics to start with, tuning adjustment on a typical superregen. receiver circuit is far greater than the permitted frequency range of 26·96 megacycles/second to 27·28 megacycles/second.

With a "tone" transmitter–receiver combination the position is a little different. A tone transmitter will produce a carrier with a frequency within the 27 megacycle band and impose on this a "tone" signal which, typically, may be anything from 200 to 1,000 cycles per second, but it will be a fixed tone. That is to say, the tone will be of a specific frequency, usually of the order of 600 cycles per second. To respond to the transmitter signal it is thus necessary that the receiver circuit be capable of decoding this particular tone.

Actually this is not a critical factor. The transmitter tone frequency is usually nominal and the receiver designed to match it will respond to a broad range of tones around this nominal value. Thus most tone receivers will respond to tone transmitters having a nominal frequency of the same order, and it is only necessary to tune to the basic carrier frequency of the transmitter. On the other hand, if the transmitter tone frequency is considerably different from the design tone frequency of the receiver circuit the combination will not work properly.

This is important to understand since most modern equipment is of the "tone" type. To ensure best results it is usual to match transmitter and receiver by employing the same make of each, since they are designed to go together; although as noted above it may be possible to use other combinations since the tone frequency adopted for design is usually, but not invariably, similar with different makes.

With conventional multi-channel equipment the transmitter produces a number of individual tones which can be signalled separately (as many separate tones as the number of channels required). Tone decoding in this case is done by the reed bank in the receiver and it is this item which must match the transmitter tones. The resonant frequencies of the individual reeds are fixed quantities and, in practice, provision is made in the transmitter circuit design to tune the transmitter tones to the individual reed frequencies.

The total tone range covered will lie within one octave, embracing all the tone channels. This octave will normally lie within the AF range of about 250 to 650 cycles/second.

In other words, with multi-channel transmitters the tone frequencies are adjustable, which may enable a particular transmitter to be tuned to match different receivers (or, more correctly, receivers with different reed banks). However, the tone tuning range is usually very limited and it may not always be possible to achieve a tuning "match" to a particular reed bank without changing component values in the transmitter tone circuits. Again, therefore, it is usual to employ the same make of transmitter and receiver to ensure suitable matching; but there is scope for using the same transmitter with different receivers.

In the case of multi-channel working with tone filters instead of a reed bank, transmitter and receiver must be of matched designs since it is unlikely that different manufacturers of tone-filter equipment will use similar tone frequencies. Tone frequencies used will also be quite different to those employed for working a reed receiver (usually much higher) and so a multi-channel receiver designed for working a reed receiver will not work a tone-filter receiver—at least not without considerable modification of component values in the tone generating circuits.

With multi-channel proportional equipment matching is even more specific. A superhet. receiver is invariably employed to start with, which demands matching to the transmitter via a crystal pair. In addition the form of transmitter signal generated is very much more complex, and only a receiver designed to decode that particular signal will respond to it. For this reason alone multi-channel proportional equipment is invariably obtained as complete outfits—transmitter, matching receiver and matched proportional actuators.

Except for proportional controls, all transmitter–receiver combinations work on the same basic principle. This is that the receiver works as an "on/off" switch, responding immediately to manipulation of an "on/off" key or press-button on the transmitter. Thus operating the transmitter key to give "signal on" produces a rise of current in the receiver circuit which either (i) pulls in a relay to close an external circuit containing a battery and actuator and causes the actuator to drive; or (ii) passes the increased current through an amplifier circuit which generates an even higher current to operate the actuator direct without an external battery.

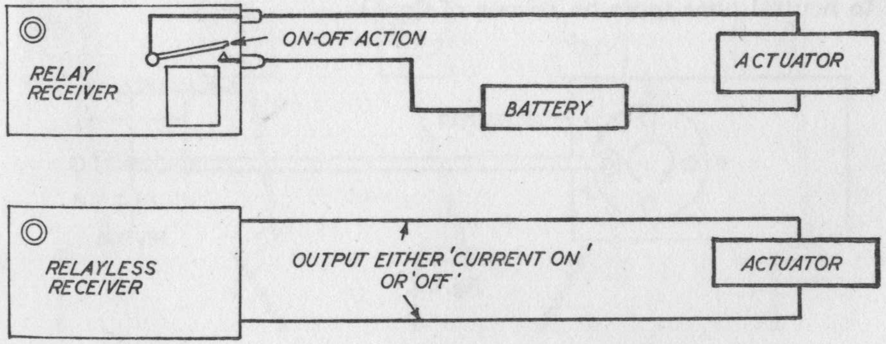


Fig. 2.1.

These two modes of operation correspond to a single-channel relay receiver and relayless receiver, respectively—Fig. 2.1. From the practical point of view all that really matters is that the receiver acts as an "on/off" switch and, provided the combination works satisfactorily, both the receiver and transmitter can be regarded as "black boxes". It needs no electronic knowledge to utilize the results they produce.

The actuator, which is a necessary addition to the transmitter–receiver combination, translates the electronic signal and its switching action into mechanical output. It is this mechanical output which moves the control being operated.

If the actuator is assumed to be a simple electric motor, then it will start as soon as the transmitter is signalled "on" and continue running as long as the signal is held. When the transmitter key is released the transmitter signal will be "off", the receiver will also respond to its "off" switching condition and the motor will stop. The next transmitter signal will start the motor running again, and so on.

This form of start/stop mechanical output, driving in the same direction each time and restarting from where it last stopped, has limited application. A practical actuator normally has a specific sequence of movements which it follows. Thus signal "on" and held on causes it to drive to a certain position and stop there as long as the signal is held on. When the transmitter signal is switched "off" the actuator then returns to its original or "neutral" position. On receipt of the *next* command it then moves in the *opposite* direction and stops, returning to neutral once more on release of signal.

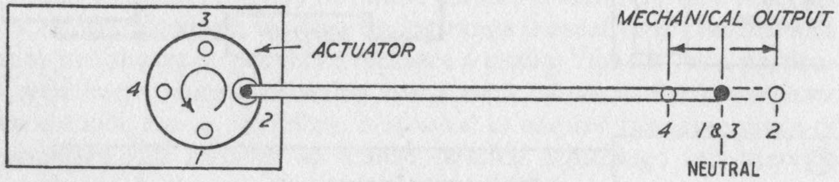


Fig. 2.2.

This form of movement is normally obtained from a rotary drive, stopped at quarter-turn positions. Mechanical output in the form of a push-pull motion or side-to-side movement can then be derived from a crank pin or crank, as shown in Fig. 2.2. Two of the quarter-turn "stop" positions correspond to "neutral", and each of the other two

quarter-turn "stop" positions provides separate mechanical movements away from the neutral position.

This is the basis of single-channel operation which can provide a practical control system for model aircraft and model boats—and, of course, for a variety of other remote-control operations which can be worked on a sequencing mechanical output, not necessarily model controls.

With moving models the main requirement is to be able to control direction, hence the rudder is the primary control with aircraft and boats. With a simple sequencing actuator, either right or left rudder can be selected at will, according to the transmitter signal actually transmitted. Thus (see also Fig. 2.3.): (i) press and hold (transmitter key or press-button) gives RIGHT rudder, (ii) press-release-press and hold gives LEFT RUDDER. On release of signal, in both cases, the rudder returns to the central position. With no signal, of course, the rudder remains in neutral.

This is a practical control system, using minimum-cost radio equipment, although it does have certain limitations. An essential feature is the *self-neutralizing* action on release of the signal. It may appear that a

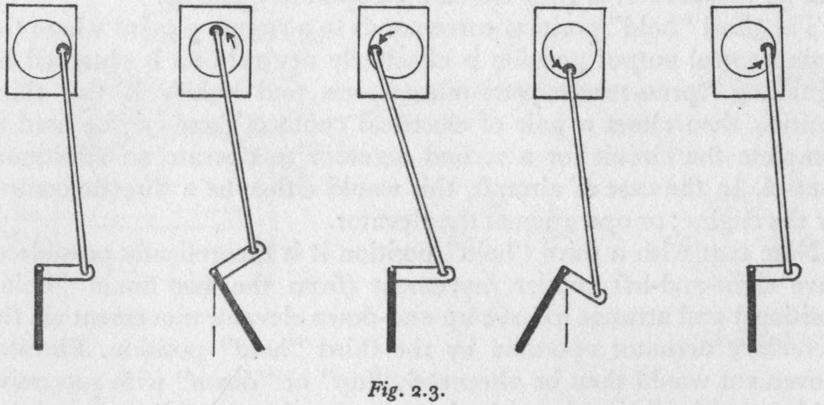


Fig. 2.3.

better form of drive would be to use an electric motor rather than an actuator to drive the rudder from side to side so that the rudder could be "inched" to any intermediate position and stopped, thereby releasing the signal. In other words, the control signal could be held on just long enough to move the rudder to any required position. This is the sort of hook-up which can work well on the bench—but it is quite impractical as a control for model aircraft, at least. It will only result in loss of control in flight. With only limited control (rudder only) it is essential that the model flies most of the time with neutral rudder and with normal "free-flight" stability, and the only way this can be achieved is with a self-neutralizing actuator. With slow-moving boats it is possible to use an "inched" rudder control, but in practice this will give less positive control than the conventional action described.

Since this action produces control movement to a full-on position, followed by reversion to neutral, it is generally referred to as a "bang-bang" type of control—"bang" to full movement one side or the other when signalled, and "bang" back to neutral on release of signal.

Some improvement in manipulation of the transmitter key is provided by using a slightly modified form of actuator. This enables the second control position obtained by "press-release-press and hold" to be signalled more quickly, making for more positive selection. Actuators of this type also commonly incorporate a third "holding" position which can be used to operate an additional control, or more usually close a pair of contacts. It is then called a compound actuator.

The third "hold" position corresponds to a stopping point where the main control output position is effectively neutral and is obtained by signalling "press-release-press-release-press and hold". If this third position then closes a pair of electrical contacts these can be used to complete the circuit for a second actuator to operate an additional control. In the case of aircraft, this would either be a throttle control for the engine; or operation of the elevator.

Note that with a third "hold" position it is theoretically possible to have right-and-left rudder movement (from the two main "hold" positions) and arrange to have up-and-down elevator movement via the secondary actuator operated by the third "hold" position. Elevator movement would then be alternately "up" or "down" with successive "third-position" signals, with elevator reverting to neutral on release of signal each time. This is one of those set-ups which will work on the bench but is not a practical system for flying, using separate escapements simply connected in this manner. It is workable with cascaded escapements, however (see Chapter 6), but still has definite limitations in the time taken to signal an elevator control.

Similar objections apply to using a 4-position non-neutralizing escapement as a secondary actuator for elevator control. Here only a "blip" of third-position signal is required to trip the actuator and make it move a quarter turn. Elevator position then follows a sequence of neutral-up-neutral-down-neutral, etc. This could be worked off a "quick blip" signal position rather than a third position for simpler signalling. This makes for faster working through the sequence for repeating a particular elevator position, but neutral also has to be selected by signalling.

Where a "third-position" elevator control is desirable the most practical solution, for ease of selecting this control, is to employ a special actuator offering a "kick" elevator movement in the "third" position, i.e. a movement either up or down, this movement being given directly from the actuator output rather than using an additional secondary actuator (see Chapter 6).

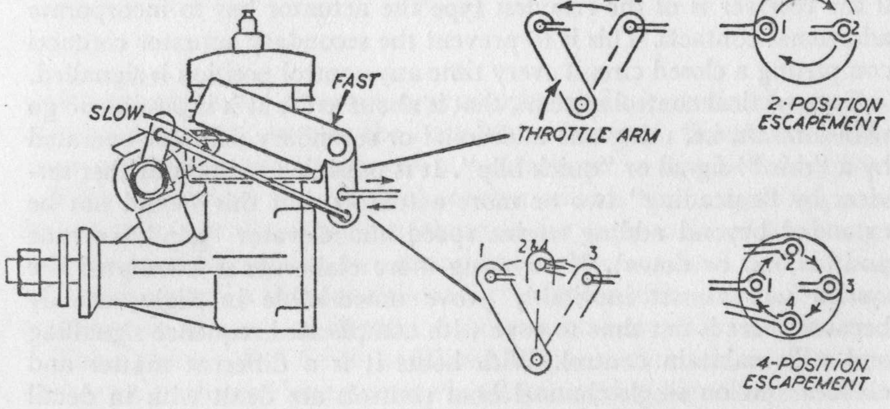


Fig. 2.4.

With a throttle control a non-neutralizing secondary actuator should be used as this will enable a throttle position to be selected by a momentary signal and the signal does not have to be held on. A 2-position actuator will then give, alternately, "high" or "low" throttle positions. A 4-position actuator will give three throttle positions in sequence—high-middle-low-middle-high, etc.—Fig. 2.4. This is a "changeover" type of control which, on receipt of signal, will produce a changeover from the last state to the next in the sequence.

With rudder as the main control, engine speed is more useful than elevator control as the additional service. In this case signalling motor speed change can be simplified by using a compound actuator with "quick blip" switching rather than a third "hold" position. It is only necessary momentarily to trip the secondary actuator to produce a changeover of the engine throttle position, and with "quick blip" facilities on the actuator this can be achieved with just a momentary blip of the transmitter key instead of having to signal "press-release-press-release-press and hold". Signalling an engine speed change is very much simpler and quicker as a consequence.

Details of actuators of these types and the way they are connected up are described in Chapter 7. It is important that the actuator used matches the type of receiver. For example, "third position" or "quick blip" switching has to be wired through the receiver relay contacts; or if the receiver is of the relayless type the actuator has to incorporate additional contacts. This is to prevent the secondary actuator contacts completing a closed circuit every time any control position is signalled.

For practical control systems, that is about as far as it is possible to go with aircraft, i.e. using one additional or secondary actuator operated by a "third" signal or "quick blip". It is possible to obtain further services by "cascading" two or more actuators, but this should not be extended beyond adding engine speed and elevator "trip" (i.e. one position, up or down). If anything more elaborate is attempted the system will almost inevitably prove unworkable in flight, mainly because there is not time to cope with complicated sequence signalling and still maintain control. With boats it is a different matter and elaborations on single-channel boat controls are dealt with in detail in Chapter 7.

With conventional multi-channel working the basic operating principle remains the same, except that it is the reed bank which operates as the switching unit. Each reed becomes a simple "on/off" switch for an external circuit completed through the reed and its

contact. Thus each reed could be used to control a single-channel actuator, giving as many separate services as there are reeds.

In practice individual reeds are not used as control switches for separate single-channel actuator outputs, except for minor ancillary services (and those usually on boats). This is because sequence control positions, which are the only type which can be provided by single-channel actuators, are not the best form of control. Control is much more positive if a particular control position can be signalled directly.

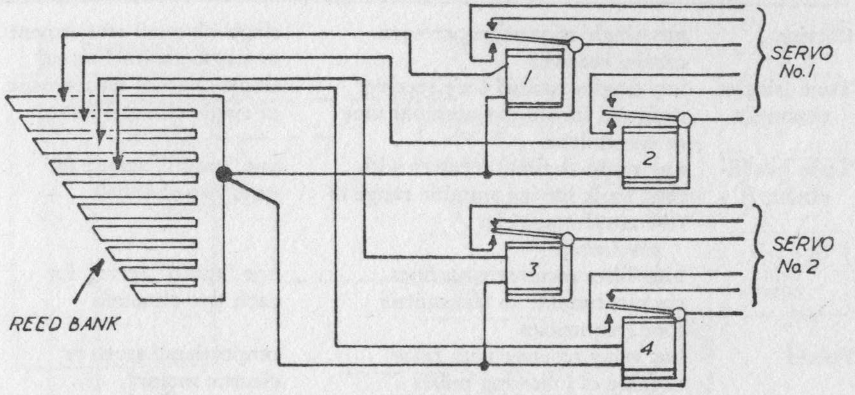


Fig. 2.5.

With a sufficient number of channels available direct signalling can be achieved by allocating two channels for each main control—e.g. two channels for rudder, two channels for elevators, and so on. Thus two reeds control a single multi-channel actuator, either through relays as shown in Fig. 2.5 or directly via a transistor amplifier circuit.

The significance of this is as follows. Suppose channels 1 and 2 are connected to the rudder actuator via relays 1 and 2. Signalling channel 1 (tone 1) then produces movement of the actuator in one direction—say right rudder; and signalling channel 2 produces opposite rudder (left rudder). These positions can be signalled from a single key on the transmitter—movement to the right producing right rudder and movement to the left, left rudder. The key would be spring loaded so that

Table 2

RECOMMENDED EQUIPMENT

*Transmitter type**	*Should operate*	*Actuator(s) required*
Carrier	any single-channel superregen. carrier receiver	single-channel escapement or single-channel servo†
Tone (single-channel)	any single-channel tone receiver designed for similar nominal tone as transmitter	single-channel escapement or single-channel servo†
Tone (multi-channel)	any multi-channel receiver with reed bank having suitable range of resonant frequencies	one "multi" servo‡ for each two channels
	alternatively	
	tone-filter receiver with filter circuits tunable to transmitter tone frequencies	one "multi" servo‡ for each two channels
Pulsed	any relay receiver with relay capable of following pulses	proportional servo or electric motor†
Proportional	specifically matched proportional receiver	proportional servo(s)
	alternatively	
	standard receiver (normally relay type) followed by a decoder circuit	proportional servo(s)

* Valve or all-transistor.

† Some all-transistor receivers may be too sensitive to use with motorized actuators. Normally, too, a relayless receiver will usually work a motorized actuator only via a slave relay.

‡ With transistor amplifier circuit if used with relayless receiver.

when released it would return to centre, giving no signal and allowing the actuator to self-centre or drive the rudder back to neutral position. Additional keys, each controlling a pair of additional channels (tones), could then be used for direct selection of up-and-down elevator, and ailerons for right or left turn. Actuator movement would still be "bang-bang", self-centring on release of signal, with as many actuators as there are pairs of reeds. Thus rudder, elevator and ailerons control, as covered above, would need six channels for operation (i.e. a 6-reed bank) and three "multi" actuators.

Two more channels and a further actuator would also provide engine speed control. Rather than "bang-bang" movement in this case it is best to use an actuator which can be "inched" to any position between its limits of movement in either direction—like the simple electric motor actuator described as impractical with single-channel systems. This sort of movement, known as a "progressive" action, can be used to advantage on secondary controls which mostly affect trim and are not main flying controls. The latter always need to be of self-centring type on release of signal with aircraft.

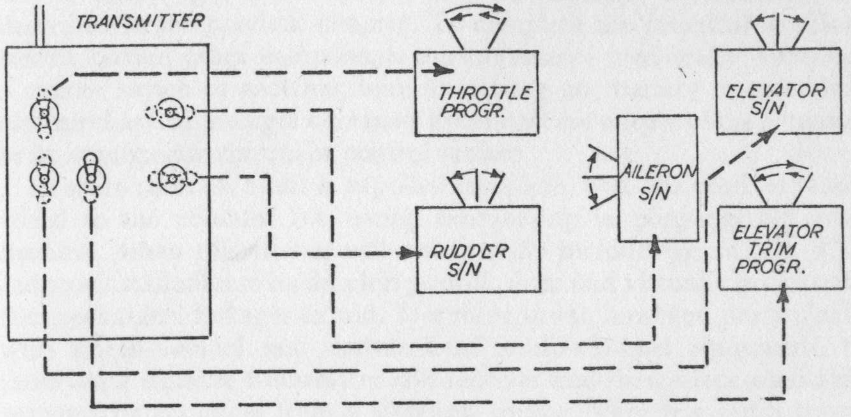


Fig. 2.6.

The advantage of using a progressive type of actuator for throttle control is that the engine throttle can be moved to any position between extremes of "high" and "low", providing the maximum response from this control. A progressive servo can also be used for providing elevator trim movement, which will be of considerable advantage; and rudder or aileron trim, which is less necessary but still advantageous in giving complete control. Any such additional services, of course, each require two additional channels for control. Complete information on the number and type of controls used with multi-channel installations is given in Chapter 10, but Fig. 2.6 shows diagramatically how with "fuel house" any control service required can be signalled directly.

Proportional control systems come into a class of their own and are best dealt with in separate chapters. Chapter 9 covers the simpler forms of "proportional" controls which can be derived from single-channel systems; and Chapter 13 deals with the much more elaborate multi-channel proportional systems.

CHAPTER 3

ANCILLARY EQUIPMENT

A COMPLETE set of radio control units comprises a transmitter, a matching receiver and a suitable actuator, or actuators, as described in the previous chapter. To complete the practical working circuit certain other components are necessary: specifically batteries, a master switch or switches, wire for wiring up, battery connections, also mechanical linkages necessary to connect the output of the actuator to its appropriate control or control surface.

In some cases an outfit is supplied complete, with the receiver ready wired to the actuator (or wiring terminating in plug-together connectors), when this wiring will also usually include the switch. This reduces installation to its simplest possible form and virtually leaves only the mechanical linkages to add. It is more usual, however, particularly with single-channel and conventional multi-channel equipment, to purchase a suitable transmitter and receiver and then select a suitable actuator or actuators from a different source. Very few radio transmitter–receiver manufacturers do, in fact, also make actuators and these are produced by specialist firms. In that case installation involves wiring up the actuator(s) to the receiver and also adding the battery circuit with its switch.

Probably the majority of equipment faults arise at this stage, due primarily to bad connections. All wiring connections, whether directly to actuators or to matching plugs and sockets for plug-together connections, must be soldered, and soldered properly, with particular attention paid to eliminating strain on soldered connections. Most installations are subject to vibration in service and this can place an additional load on soldered joints which are already under strain, leading to early failure. This, and other troubles which can be caused by vibration, is an installation problem and is covered more fully in Chapters 6, 7, 10 and 11. As far as this chapter is concerned the point to be covered is soldering.

Soldering should always be done with a small electric iron, using resin-cored solder specially produced for electrical work—a 60/40 alloy in preference to general-purpose solder which usually has a lower tin content. This will require the lowest bit temperature, reducing the risk of damaging electrical components by overheating. A 20-watt iron should be satisfactory for most work, with a $\frac{1}{8}''$ or $\frac{3}{16}''$ bit. For work on very small connections (miniature plugs or crowded printed circuits), a 10-watt iron with a $\frac{3}{32}''$ or even a $\frac{1}{16}''$ bit is preferable. The smaller the bit the more rapidly it will lose heat in making a joint and the longer it will take to heat up again before it can be applied to the next joint. No additional flux is needed apart from that already contained in the cored solder. *Acid type fluxes should never be used for electrical work.*

Good soldering depends basically on (i) the bit of the iron being hot enough to melt the solder rapidly; and (ii) the joint surfaces being really clean. Solder tags and other connecting points should be scraped clean or rubbed with fine emery, even if tinned and new, until they appear really bright. Wire ends are usually stripped immediately prior to completing a joint and so should not need cleaning unless they are accidentally handled by the fingers.

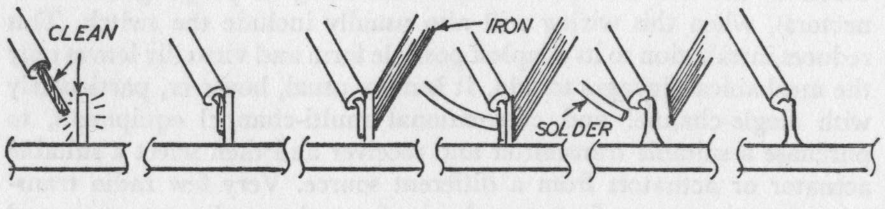


Fig. 3.1.

The correct way to make a soldered connection is shown in Fig. 3.1. After cleaning and preparing the wire end by stripping insulation back about $\frac{3}{32}''$, apply the bit of the iron to one side of the most rigid member of the joint (e.g. a solder tag). Position the bare wire end and apply solder from this side, so that it melts and runs smoothly over the joint. Remove iron and solder and blow on the joint to cool before releasing the wire as otherwise it may pull free whilst the solder is still molten.

Such a joint should be completed in 3 or 4 seconds at the most. If the solder does not melt properly in this time, then either the iron is not hot enough or is too small for the job, e.g. too much heat is being absorbed by a large joint area. The result in either case will be a "dry joint". The solder will have a rough, crystalline appearance and the joint will be weak. It will probably also be a very poor electrical connection.

If the solder runs right off a joint without sticking, then the joint surfaces are dirty or greasy and need cleaning. No amount of further heating will produce a satisfactory joint in such cases. It will usually only make matters worse. Similarly, if the solder collects in a blob rather than spreading all over the joint area, the joint surfaces are dirty. With a good joint the solder should flow smoothly and evenly all over the joint and retain a bright appearance when cool. Fig. 3.2 illustrates good and bad soldered joints.

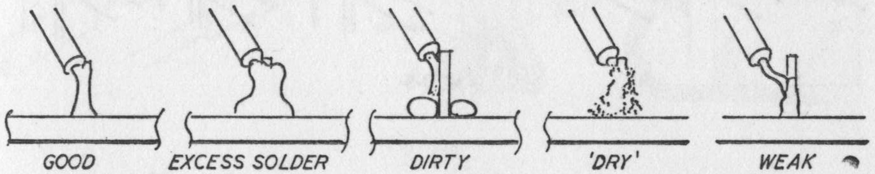


Fig. 3.2.

Besides the joint surfaces it is also necessary to keep the tip of the iron clean and well tinned. The tip will tend to get dirty after a period of use, but can normally be wiped clean when hot with a rag. It will only need cleaning with emery or a file if the tip has been allowed to get into a very dirty state and become pitted.

A good soldered joint is permanent and as reliable as an electrical connection. It is also strong mechanically, but as noted earlier this latter feature should not be used to justify tight wiring runs between two points. It is also unnecessary to add mechanical strength to a soldered connection by winding wire around a solder tag.

Thus either method A or B (Fig. 3.3) is quite satisfactory for making off a wire to a tag with a hole. Binding the wire in place as in C is quite unnecessary, and you will probably "finger-print" the wire in doing so, with the possibility of producing a dry joint. Similarly either method D or E is satisfactory for making off a wire to a straight tag. Method F is clumsy, unnecessary and needs more heating time to complete. Giving the wire end some support, as in A and D, has the advantage of helping to hold it in place whilst the joint is being made.

To complete a first-class job, wiring connections of this type should be "sleeved". Before making the joint, a short length of sleeving is cut and slipped over the wire end. After making the soldered joint and allowing it to cool the sleeving is then pushed up right over the joint, as shown in Fig. 3.4. Certain types of plastic tubing can be used for "shrunk fit" sleeves. This tubing is cut to length and used as a normal sleeve, selecting a diameter which is easy to push in place. If the sleeving is then painted with dope thinners it will shrink to a very tight fit, adding strength as well as protection to the soldered assembly.

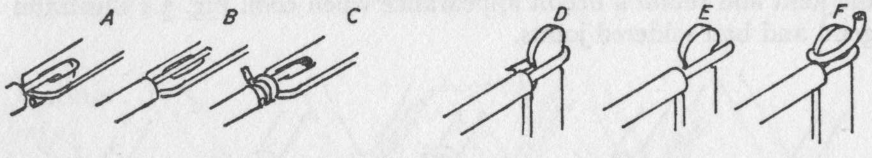


Fig. 3.3.

In the case of wiring to a servo all the wires can be taken in an easy bend with a generous amount of slack to one face of the servo and bound in place. This will ensure that no mechanical stress is likely to be placed on the soldered connections through vibration, etc; and the servo could even break loose in a crash landing, still without straining the joints.

The importance of completing good soldered joints in all connections which have to be made to complete the wiring installation cannot be over-emphasized. Proficiency comes only with practice, but applying the elementary rules of a sufficiently hot iron and clean joints should produce adequate results to start with. If not, then practise soldering on scrap components until the technique has been mastered. It is foolish to risk damage to high-cost equipment through a radio failure caused by a bad connection producing a crash.

The type of wire used for wiring installations should be the same as that used by radio control manufacturers. Receivers and "multi" servos are normally supplied with wire leads connected internally. Additional wires may be required for battery leads, etc.

Stranded rather than solid wire should always be used. Small-diameter stranded wire is usually designated by two numbers separated by /. The first number refers to the number of strands and the second number the actual diameter of the wire in inches. Thus 12/004 means twelve strands of 0·004″ diameter wire. Anything less than 12 strands is not to be recommended for radio control wiring. 12/004 wire is suitable for all general wiring, and larger-diameter wire—e.g. 14/0076 for battery leads and escapement wiring on single-channel circuits.

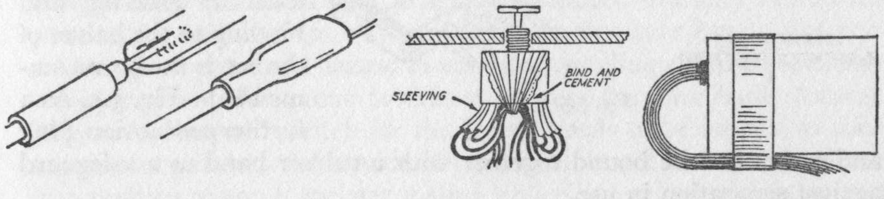


Fig. 3.4.

Stranded wires of these sizes are readily available with coloured plastic insulation, the range of colours available making it easy to plan and identify circuits by colour code. There are no overall standards as regards colour code, however, but black is a normal choice for an "earthed" or negative battery connection and red is a usual choice for a positive battery connection. Different manufacturers of equipment may use the various other colours in a number of different ways. Thus receiver leads, etc., can be identified only by reference to the manufacturers' instructions or wiring diagram giving the appropriate colour code used.

It is not always convenient, or desirable, to take wiring directly from one component to another, particularly with multi-channel installations where a large number of different wires may be involved, many with common connections. In such cases wiring may be "broken" between the receiver and the bank of actuators, etc., by terminating on a multi-pin plug; with the corresponding "follow through" wiring made off on a matching socket. This can make for a much tidier installation and even reduce the amount of wiring required. At the same time it enables individual components, such as the receiver and single actuators, to be unplugged and withdrawn, if necessary without having to unsolder joints.

Miniature multi-pin plugs and sockets suitable for such jobs are available with up to 12 or more separate through connections. They are generally perfectly reliable, although individual insulation of leads by sleeving and binding to the halves of the set is to be recommended—Fig. 3.5. As a further precaution, plug and socket can be bound together with a rubber band as a safeguard against separation in use.

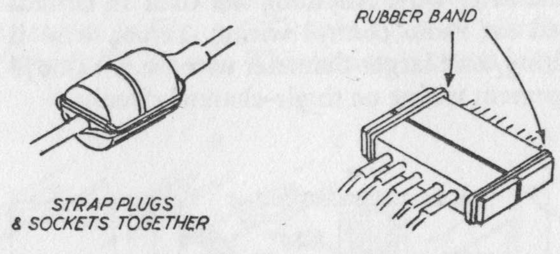


Fig. 3.5.

Single-channel circuits incorporate far less individual wires and where only two, three or four wires are to be "broken" the larger circular-type plug and sockets are often preferred. These are usually so tight fitting as to need no binding together; but as a general rule with *all* plug-together connections with *all* types of radio gear, the possibility of the two halves of the connection working apart under vibration should be eliminated with a rubber band binding. The extreme case is where separate receiver units may plug together. Although the fit may be quite tight, it is essential to bind the assembly tightly together with a stout rubber band.

Switches would appear to need little comment. They are simple mechanical devices and their action is straightforward. However, not all types of switches are consistently reliable as regards contact pressure and thus contact resistance, particularly in the small sizes. This can be a critical factor in operational performance of the circuit where low voltages are usually involved.

Basically a toggle-type switch can be expected to have a more

consistent performance than the slide-type switch, which is cheaper to produce. However, there are good and bad designs with each type, and variations in performance between individual switches. With miniature-size switches, too, there is likely to be even greater variation in performance. Choice of a suitable switch should be based on recommendation, i.e. a type that other radio control modellers find successful; or at least a type sold specifically as being suitable for radio control circuits.

Most modellers tend to use oversize switches and plugs, and generally this provides a safety margin as regards performance. Logically, however, modern radio control units are miniaturized and should also employ miniaturized ancillary components in the complete circuit. Quality components in miniature size are, however, expensive, which is why many modellers tend to stick to standard ordinary radio components for switches, etc. A poor switch, on the other hand—like poor soldering—represents a hazard to consistent working and is no economy.

Switches are also prone to failure because they are badly located. The main "on/off" switch for the circuit needs to be located at some convenient point on the outside of the model, but it must not be placed in a position where it can get soaked with oil (e.g. from the exhaust of an engine), or damp. It is far better to have a switch in a less convenient position if this means that it is fully protected from exhaust waste, spray, rain, etc.

Batteries for powering radio circuits are a separate subject on their own. As far as installation is concerned they are simply another component to be connected up. To assist in this direction the battery may or may not be fitted with terminals.

Miniature high-voltage batteries, such as employed with valve circuits, normally have press-stud connections. In such cases the battery leads need only be soldered to mating studs and connection completed by pressing on to the battery terminal points. Battery press studs are "polarized" as regards size and shape and so the wrong lead cannot be pressed on to the wrong terminal and so accidentally reverse the polarity of the circuit. Lower-voltage dry batteries, such as may be used in transmitters, also usually have either press-stud connections or polarized plug-and-socket connections and again are easily replaceable without danger of reversed polarity connection.

Most modern receivers operate on a low voltage supply, typically from 3 to 6 volts. This can be met by lightweight dry batteries, or miniature accumulators. The former have the advantage of being cheap, but for overall reliability and from the general performance point of view, rechargeable accumulators of the nickel-cadmium (DEAC) type are very much to be preferred. DEAC batteries have, in fact, become virtually a standard choice for receiver and servo battery power for all serious radio control work.

Dry batteries, particularly of pen cell size, still remain popular for very small models or lightweight installations; or where initial cost must be kept down to a minimum. Some of the weight and bulk advantage is lost if such batteries are mounted in a battery box for ease of connection. Also unless dry batteries are tightly clamped or bound in a battery box they can become dislodged and produce a supply failure (or in certain circumstances, intermittent operation).

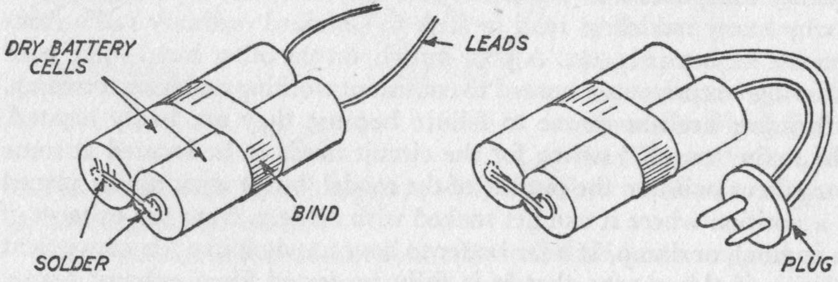


Fig. 3.6.

The most positive way of obtaining good connections with small dry battery supply is to solder up connections to make a battery "pack", as shown in Fig. 3.6, complete with main battery leads. These leads are then soldered to a two-pin plug, with the corresponding circuit battery leads soldered to a matching socket. Several packs can be made up in this fashion—e.g. as many as are likely to be immediately required—and are easily connected or replaced. The plug is salvaged after a pack is removed for fitting to a fresh pack.

The best type of dry battery to use is without question the new "high-energy" cells which have a far superior performance and greater consistency than ordinary dry batteries. Unfortunately since the casing on these cells is of steel it is extremely difficult to solder on connections to make up a battery pack in the manner described. It may, in fact, prove impossible to produce reliable connections this way, even after cleaning the battery terminals with a file. In such a case the cells have to be mounted in a battery box with spring connections.

DEAC batteries are available with both press-stud and solder-tag terminals. Press-stud connection can be fitted only to end cells, i.e. a complete battery. In many installations the DEAC battery is tapped at one or more voltage points in addition to connections to the ends and this can only be done by soldering the appropriate leads to tags at the tapping points.

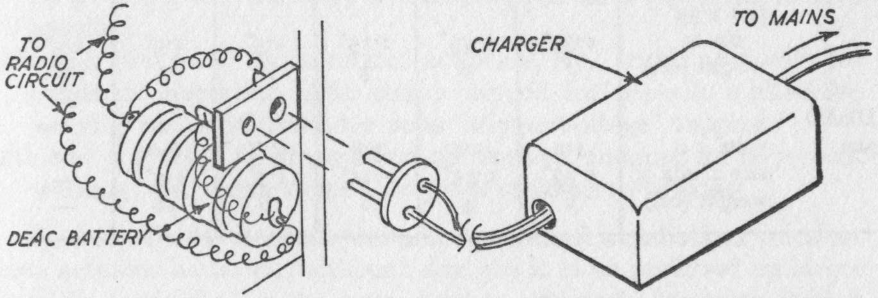


Fig. 3.7.

Since a DEAC battery is rechargeable it can be mounted permanently in the model, i.e. with all leads soldered to appropriate tags on the DEAC. Additional leads can then be taken to a two-point socket, as shown in Fig. 3.7. to allow a charger to be plugged in. This is generally preferable to removing the DEAC each time it has to be charged and also permits the use of positive soldered connections.

The recommended charging rate for DEAC batteries is 25 milliamps for size 225 cells and 50 milliamps for size 500 cells, both giving a full change in approximately 12 hours. In practice DEACs are not fully discharged—or should never be allowed to discharge completely—and

Table 3

DEAC BATTERIES (STANDARD PACKS)

	No. of cells	1	2	3	4	5	6
DEAC 225	volts	1·2	2·4	3·6	4·8	6·0	7·2
	size 1″ dia ×	0·36″	0·71″	1·1″	1·45″	1·8″	2·15″
	weight (oz)	0·5	1	1·5	2	2·5	3
DEAC 500	volts	1·2	2·4	3·6	4·8	6·0	7·2
	size 1·35″ dia ×	0·39″	0·75″	1·15″	1·5″	1·9″	2·3″
	weight (oz.)	1	2	3	4	5	6
DEAC 500	volts	1·2	2·4	3·6	4·8	6·0	—
	size 2″ dia ×	0·39″	0·75″	1·15″	1·5″	1·9″	—
	weight (oz.)	2	4	6	8	10	—

are normally recharged after every session of use. Unlike lead-acid accumulators, there is no indication as to when a DEAC is fully charged, but an overcharge at the currents recommended will not be harmful, even if prolonged for several hours. A high charging current for an excessive time on charge can, however, result in permanent damage to the cells, which become overheated and distort, although the battery may still be workable. With reasonable treatment, DEAC cells are virtually indestructible and have an almost indefinite life. Thus their initial high cost is more than justified by the extensive use which can be got out of them.

A wide variety of charging units are available for recharging DEACs, designed to provide a suitable charging current consistent with typical DEAC battery voltages. A single DEAC cell produces 1·2 volts. Standard battery packs consist of two to six cells, welded together and with end and tapping point terminals. Commercial battery packs of this type are to be preferred to home-made packs assembled from individual cells as the latter need clamping together to ensure consistent contact between individual cells, increasing the bulk and weight of the pack.

Typical applications of standard DEAC battery units are:

Two cells (2·4 volts)—for lightweight escapements capable of operating efficiently on 2 volts.

Three cells (3·6 volts)—for most escapement or motorized actuators designed for 3-volt operation; also all-transistor receivers designed for 3-volt operation.

Four cells (4·8 volts)—for heavier type escapements or motorized actuators designed for 4·5-volt working; also all-transistor receivers designed for 3- to 4·5-volt working; or centre tapped for 2·4-volt multi-servo working.

Five cells (6·0 volts) for motorized actuators, etc., requiring 6 volts for consistent operation. Also centre tapped for 2·4-volt multi-servo working with additional 1·2 volts "trigger voltage" tapping.

Six cells (7·2 volts) for transmitters or receivers designed for 6–7·5-volt working; also centre tapped for 3-volt multi-servo working.

Size 225 DEAC is usually suitable for aircraft installations (receiver and actuator batteries); although size 500 is to be preferred on larger models, especially for the servo battery, although battery weight is doubled (see Table 3). Size 500 is to be preferred for boat installations. Size 1000 is best for heavy-duty applications where the weight of battery is not important, e.g. for transmitter low-voltage supplies.

CHAPTER 4

COMMERCIAL EQUIPMENT

VIRTUALLY all the successful radio control of models is carried out with commercial equipment—that is, transmitters, receivers and actuators which have been purchased as ready-made items. There are, of course, the exceptions—the particularly gifted amateur radio enthusiast or trained electronic engineer who can both design and make original equipment, but it still needs a practical knowlege of modelling to make it successful. Put the two together and you will probably find that the individual concerned is a manufacturer of commercial equipment, for that is how most of the more successful firms in this highly specialized field started.

Once a successful transmitter or receiver is produced commercially, of course, there is nothing secret about it. Its circuit can be worked out, component values are readily found and it could be duplicated by anyone with reasonable ability in practical electronics. The circuit may also be published, which saves having to examine the actual product to find out what the design involves. Yet it would probably cost nearly as much to copy it—more, if the cost of time involved is taken into account—and the results achieved would almost certainly not be as good.

This is even more true in the case of actuators. Escapements for single-channel use as actuators rely implicitly on very accurate construction for consistent performance. Quite a proportion of commercial escapements, even, are not really good enough in this respect. The better products may have involved an investment of thousands of pounds in development and tooling. They are expensive as a consequence, but they are worth it because they do have the performance required. However much you pay for a piece of unreliable radio control equipment it is not worth anything and may in fact cost you the price of extensive repairs to the rest of the equipment. This applies particularly in the case of radio control for model aircraft where malfunctioning of the equipment can result in a crash and extensive damage. With other

subjects, like boats, which are not so liable to suffer damage through loss of control, lack of reliability is more of a nuisance than a hazard.

Reed banks for multi-channel receivers, and servos for multi-channel actuators are other items which just cannot be home made with any hope of real success. The hard fact has to be faced that these are expensive items which just have to be bought ready made, if you are looking for reliable radio control performance. And there are no such things as "economy prices" in this sphere. Basically you get exactly what you pay for. The fact that an item remains in production for a long period is virtually an assurance that it does so on merit; and if it retains a high price it does so because it is worth it, although as with everything else there may be the exceptions.

Some prices of equipment are artificial since these items are imported. The United States is by far the biggest producer of radio control equipment and generally recognized as world leaders both in the establishment of performance and design standards and in the quality of commercial productions. As a consequence there is a large demand for American radio control items from leading radio control modellers all over the world, despite the fact that prices may be inflated by import duties and other taxes.

Japan, a later starter, rose to second largest producer by 1966—certainly as far as variety of equipment, virtually all based on American standards but also incorporating some original thinking. Japan has particularly evolved some outstanding products in the actuator field, both escapements and servos, which compare in performance with the world's best. Prices, after importing, are generally comparable to, or slightly lower than, American counterparts.

Britain, until comparatively recently, concentrated largely on the lower-cost single-channel field; and the market for multi-channel equipment has never been large enough to support more than one "quantity" manufacturer. This is in direct contrast to the United States where, in the heyday of conventional multi-channel, there were more than a dozen manufacturers in direct competition, all turning out quite large numbers of sets. And although British-made equipment in both single-channel and "multi" is now comparable with American standards it still lacks the variety and reputation of leading American counterparts.

Commercial radio equipment is judged on the reputation it gains for performance and reliability in use, regardless of the country of origin. In the contest world the bulk of equipment used has been, and still continues to be, American in origin. In this exacting field, in fact, the only true users of "home-manufactured" equipment have been the Americans and the Germans.

Germany is the one country which has, to date, developed radio control equipment on lines entirely different to American standards. The leading German manufacturers soon abandoned the reed bank in favour of tone filters for multi-channel working, and virtually ceased production of single-channel equipment completely as soon as "multi" became a practical proposition. They thus committed themselves to a far more expensive market, with the obvious possibility of lower sales for a specialized product. To counter this, and make such equipment suitable for anyone to handle, they adopted pre-wiring as standard with plug-together circuitry, eliminated all need for adjustment as far as possible, and even adopted plug-together modules for receivers so that a customer could add to and expand the scope of existing equipment. No knowledge of radio at all—or even modelling—is needed to plug together an 8- or 10-channel outfit of this nature and immediately get it working satisfactorily. For that reason alone such equipment has an immediate appeal for any modeller who wants to dodge all electronic problems and wiring-up jobs; but the equipment is more expensive than conventional multi-channel as a consequence, and specifically tied to the use of certain matching servos for plug-together installation. It can, however, be rewired to match other types of servos.

In considering the purchase of necessary equipment normal practice is to decide on a particular make of transmitter and matching receiver and then consider the actuator separately. Choice may be narrowed down in certain cases, e.g. radio control for a small model calls for a miniature relayless receiver, of which the numbers produced are more limited. This will also limit choice of possible actuators—i.e. miniature in size and matched to the output of the relayless receiver.

Choice is also influenced by the purpose of the equipment. For model aircraft control lightweight equipment is desirable, even for quite large models. Also it is a decided advantage to have a compact hand-held transmitter for ease of holding and turning to follow the model in flight. This favours an all-transistor transmitter with its smaller size and much lighter weight. On the other hand some of the smaller all-transistor transmitters may suffer from lack of range (really lack of output power) for the successful operation of certain receivers in model aircraft. Thus the sensitivity of a superhet. receiver is usually better than that of a superregen. receiver, and that of a tone receiver is better than that of a carrier-only receiver. The same transmitter may produce adequate range with a superhet. receiver; marginal range with a tone superregen. receiver; and insufficient range to operate a carrier receiver.

Normally, however, matched transmitter–receiver combinations, as produced by an individual manufacturer, can be expected to have adequate range for aircraft use. In figures, this is about 300 to 400 yards minimum, as established by a ground-to-ground check. This will be equivalent to a ground-to-air range of a mile or more. Normally one would not attempt to fly an aircraft anything like this distance away from the transmitter as it would appear merely as a speck and it would be impossible to tell which way it was flying. For boats, cars and other working models a very much lower range is adequate.

So many factors are concerned which affect the choice of equipment that it would take a whole book to describe them all. For general guidance, therefore, main points are summarized under individual headings.

Transmitters for Aircraft (single or multi-channel)

(i) Preferably all-transistor for ease of handling; but be sure to use a matching receiver which is known (or, better still, guaranteed) to give adequate range (300-400 yards minimum, ground-to-ground).

(ii) Hand-held valve-type transmitters—still best where range is critical and really best for all superregen. receivers. Battery weight may be heavy, however, and battery replacement cost high since current drain may be high.

Transmitters for Boats

(i) All-transistor for portability and ease of manipulation. Range is not a primary factor.

(ii) Hand-held valve-transmitters—for multi-channel work, if preferred.

(iii) Ground-standing transmitters. Keying, in the case of single-channel, can be via a long lead and microswitch. For multi-channel work either the operator has to bend over the transmitter or extract the control switches on a separate panel connected by leads. An advantage of this type is that they can be powered by large batteries giving long battery life; or from an accumulator and a suitable converter circuit.

Note: ground-standing transmitters with an 8-ft. aerial can normally be expected to give the best range of any type. They are seldom, however, used for aircraft these days, but the above notes apply.

"Carrier-only" or "Tone"?

The tone transmitter (in combination with a tone receiver) is to be preferred for all applications. For minimum cost, however, a carrier transmitter and carrier receiver can give satisfactory results for single-channel working.

Transmitter Batteries

Sealed lead-acid accumulators or DEACs are to be preferred for low-voltage transmitter batteries, although initial cost is high. Designs capable of accepting such batteries are to be recommended. Valve transmitters, however, require the use of a high-voltage battery in addition to a low-voltage battery; the former can be provided only by a dry battery of suitable type

Single-channel Receivers

(i) For minimum size an all-transistor relayless receiver is required. This should work off a single 3–4·5-volt battery.

(ii) A relay-type receiver is almost always required to work a motorized actuator (used instead of an escapement). If preferred a relayless receiver can be used connected to the motorized actuator via a slave relay.

(iii) A relayless receiver is generally to be preferred for aircraft installations as it is not affected by vibration; but see (ii) above.

(iv) A relayless receiver is apparently to be preferred for boat applications as there are no relay contacts to corrode. However, an actuator for a boat is invariably a motorized type and needs an intermediate relay in any case between the receiver and actuator. A relay-type receiver might just as well be used in the first place and the receiver installation properly protected (see Chapter 7).

(v) Valve-type single-channel receivers are not normally used these days and have no real advantages.

Multi-channel Receivers

(i) A reed-type receiver is the conventional solution. This can be all-transistor (preferred for minimum weight and minimum battery requirements); or valve–transistor (the latter possibly being a preferred type for boats).

(ii) Performance of a reed receiver will be as reliable as its reed bank.

(iii) There is little economy in buying other than a 10-channel reed receiver (except for boats) as the cost is little higher than a 6- or 8-channel receiver. All the reeds need not be used, but they are there for subsequent extension of services if required.

(iv) A relayless type receiver is preferred, especially for aircraft. This will, however, increase the cost of actuators (servos).

(v) A tone filter receiver may be preferred. This will usually be a relay type and the use of other than specially matched actuators may demand modification of external wiring.

Single-channel Actuators

For aircraft up to about 4 ft. span escapements are normally used. Buy only escapements of sound reputation and base selection on the following requirements:

(i) 2P S/N (2-position, self-neutralizing) for rudder only.

(ii) 2PC S/N (2-position compound, self-neutralizing) for simpler control selection.

(iii) 2P or 4P (non self-neutralizing) for a secondary actuator (e.g. for engine speed changeover or elevator "trip".

Where a compound escapement is used to provide motor speed changeover as well as the main rudder control, a "quick blip"-type unit is preferred. This can be used with any relay-type receiver. To match a relayless receiver a compound escapement must incorporate an additional set of switching contacts to produce "quick blip" or third-position electrical contact switching for a secondary actuator.

For larger aircraft, and for all sizes and types of boats and car models, a single-channel motorized actuator should be used instead of an escapement. These are usually of "compound" type, and many have the "compound" action specially devised for boat use—e.g. rudder control plus contacts for switching the main electric motor drive in a boat directly without having to go through a secondary actuator.

Multi-channel Actuators

These are normally called "servos" and all follow a common pattern in being motor driven with built-in switching to produce a "stop" or "hold" at full control position and then an automatic return to neutral on release of signal (although in some cases return to neutral may be by spring action). The self-centring action can be eliminated by a simple wiring or connection modification so that the same servo can be used as a "progressive" type.

Such servos are designed for use directly connected to relay-type reed receivers. For use with relayless receivers the same servo is used but connected via a transistor amplifier circuit (usually accommodated within the servo case). The servo may then be specified as a self-neutralizing type (for main controls) or progressive (for trim controls) as the servo amplifier circuits are slightly different in each case. Equally a self-neutralizing servo with transistor amplifier may be adapted for progressive action by a wiring modification (usually involving disconnecting part of the internal circuit).

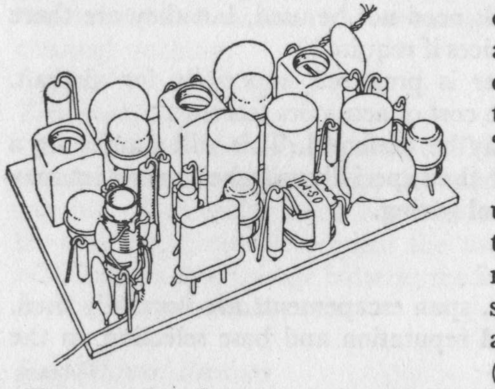


Fig. 4.1. Modern all-transistor superhet. receiver.

The best advice that can be offered as regards choosing a multi servo is to buy the best available, even if it is the most expensive!

Comparative costs of different types of equipment are summarized in Table 4. These are only general figures, but do give a good idea of the difference between the cost of single-channel and "multi", and in

Table 4

COSTS

Type of Equipment	Item		U.K. Cost	
			British made	*Imported*
Single-channel	Relay Receiver (Superregen.)		£6–£8	£6–£14
	Relayless Receiver (Superregen.)		£6–£9	£7–£12
	Relay Receiver (Superhet.)		—	£18–£25
	Relayless Receiver (Superhet.)		—	£20–£35
	Transmitter		£7–£12	£10–£20
	Escapements		£1 15s.–£3 10s.	£3–£6
	Servos		£2–£4	£2–£6
Multi-channel (Reed)	Relay Receiver	4-chan.	£19–£25	—
		6-chan.	£23–£26	—
	Relayless Receiver	6-chan.	£14–£25	£15–£30
		2/10-chan.	£10–£30	£15–£30
		2/10 Superhet.	£26–£35	£30–£50
	Transmitter	2-chan.	—	£15–£20
		4-chan.	£20	£20–£30
		6-chan.	£20–£25	£20–£30
		8-chan.	£30	—
		10-chan.	£40–£45	£45–£55
		12-chan.	£45–£50	£50–£60
	Servos Relay Receivers		£3–£5	£4–£7
	Relayless Receivers		£6–£8	£8–£10
Multi-channel (Tone Filter)	Receivers *(Superregen.)	2-chan.	—	£20–£22
		3-chan.	—	£22–£27
		4-chan.	—	£30–£35
		5-chan.	—	£36–£40
		6-chan.	—	£40–£50
		8-chan.	—	£50–£55
		10-chan.	—	£65–£70
	Transmitters	2-chan.	—	£20–£25
		3-chan.	—	£25–£35
		4-chan.	—	£30–£45
		5-chan.	—	£35–£45
		6-chan.	—	£35–£45
		8-chan.	—	£45–£50
		10-chan.	—	£55–£60

*Superhet. Receivers approx. £20 more.

Table 5

EQUIPMENT REQUIRED

(Aircraft Control Systems)

Control System	*Receiver*	*Transmitter*	*Actuator(s)*
Single-channel:			
(i) Rudder only	Single-chan.	Single-chan.	One s/n
(ii) Rudder + motor speed	Single-chan.	Single-chan.	One s/n compound + one s/n simple
(iii) Rudder + motor speed + elevator	Single-chan.	Single-chan.	Two cascaded compounds + one s/n simple
Multi-channel:			
(i) Rudder	2-channel	2-channel	1 multi-servo
(ii) Rudder + engine speed	4-channel	4-channel	2 multi-servos
(iii) Rudder + engine speed + elevators	6-channel	6-channel	3 multi-servos
(iv) As (iii) + coupled aileron-rudder	6-channel	6-channel	4 multi-servos
(v) Rudder + engine speed + elevators + ailerons	8-channel	8-channel	4 multi-servos
(vi) As (v) + coupled aileron-rudder + elevator trim	8-channel	8-channel	5 multi-servos
(vii) Rudder + engine speed + elevators + elevator trim + ailerons	10-channel	10-channel	5 multi-servos
(viii) Rudder + engine speed + elevators + elevator trim + ailerons + ailerons (or rudder) trim	12-channel	12-channel	6 multi-servos

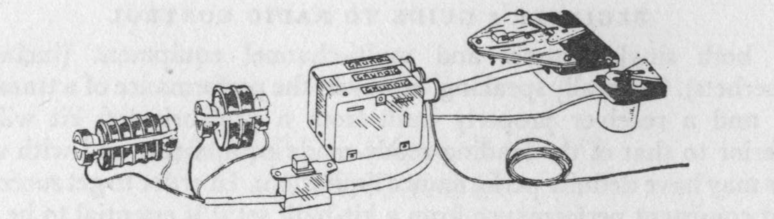


Fig. 4.2. Plug-together commercial equipment (no soldering required).

particular how the cost of a "multi" installation tends to rise with an increase in the number of channels used.

The only realistic way in which some saving can be realized is to build the transmitter and receiver from prefabricated kits. These are normally based on sound designs, with selected components, and are available

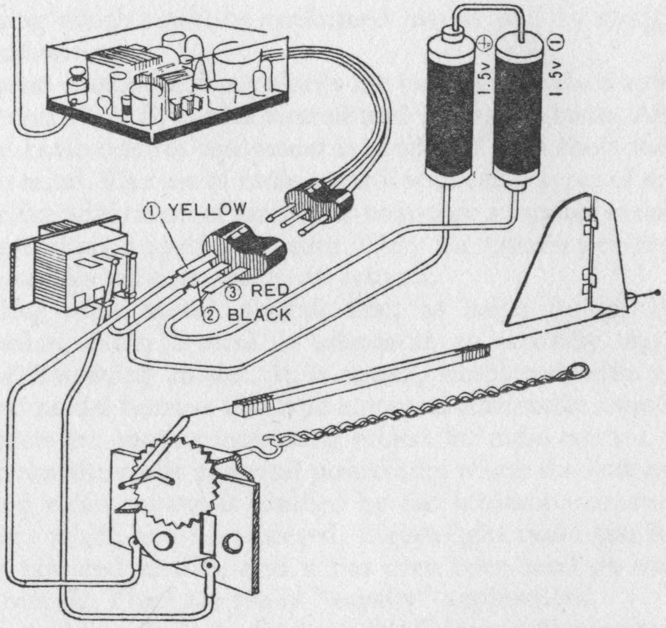


Fig. 4.3. Typical wiring up of a modern single-channel relayless receiver.

for both single-channel and multi-channel equipment (including superhets). Generally speaking, however, the performance of a transmitter and a receiver properly built from a prefabricated kit will be inferior to that of the leading ready-made equipment, and with some kits may have definite performance limitations. In order to get successful and consistent performance from a kit-built set it is essential to be able to solder properly. Also some knowledge of setting up a transmitter and receiver for maximum performance is required; and satisfactory alignment of a superhet. receiver may prove impossible without special equipment.

CHAPTER 5

MODELS FOR RADIO CONTROL

Any type of working model lends itself to remote control by radio, provided it is large enough to accommodate the necessary receiver and actuator(s). However, control demands are quite different with different types of models, and some subjects are far more interesting and rewarding than others when radio controlled. Thus remote control of a model aeroplane in flight is a real achievement possible only with radio whereas, say, the remote control by radio link of a set of points on a model railway system is a novelty and an expensive way of doing something which could be performed just as well by straightforward electrical wiring.

In terms of scope and popularity the two main fields of application of radio control are (i) model aircraft and (ii) model boats. All the commercial radio control equipment is produced with these two applications in mind. The use of radio control with other types of models may require the adaptation of aircraft or boat-type actuators to suit; or even call for making a special actuator. Only the transmitter–receiver link can be considered common to all systems.

Dealing with model aircraft first, as being by far the largest application, radio control is adaptable to virtually any size and type of free-flying model. It is usually employed with an engine-powered model because this type ensures a reasonable length of flight; but gliders are another interesting subject for radio control. These two types cover the really practical possibilities where the cost and trouble of fitting radio control is justified by the substantial increase in performance which can be achieved. Lightweight radio can be fitted to rubber powered models, and it has even been used on small indoor flying models. These are really "novelty" applications.

A normal free-flight model has a good degree of automatic stability built into the design. That is to say, when properly trimmed it will recover to its normal flight path if disturbed, say, by a gust of wind. It will also return after being deliberately disturbed from its normal flight path, say by momentary movement of the rudder.

This is the basis of the simplest form of radio control—rudder-only, as it is called. It needs only single-channel equipment and a simple actuator to be able to signal either "right" or "left" rudder, with the rudder reverting to neutral when no signal is being given. The model is essentially still a free-flight design, with remote control of rudder.

Rudder-only control has many limitations. If rudder control is held on, for example, the model will go into a spiral dive. To produce a turn the rudder control has to be "blipped" on, releasing the rudder before the model has started to bank excessively, then blipping on again to maintain the turn, and so on. The design layout is usually modified slightly as compared with an ordinary free-flight model to assist in making "blipped" turns, the main difference usually being a reduction in dihedral on the wings. Typical design is shown in Fig. 5.1.

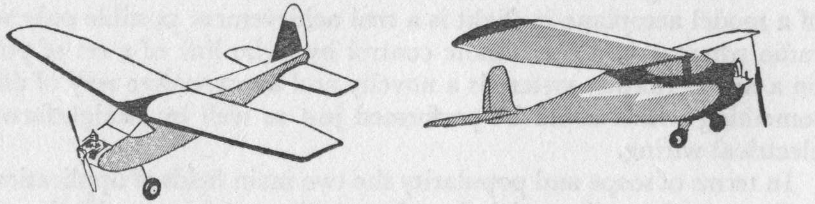


Fig. 5.1.

With practice it is possible to achieve good control for turning the model in flight, and thus controlling its direction. It needs practice to produce smooth flying with single-channel rudder-only, for a model will tend to nose down and pick up speed when turning and then zoom and tend to stall when control is released to return the model to straight flight. Again these unwanted tendencies can be minimized in a good design, allied to a proper trim. Thus the best results are obtained with a model designed for rudder-only radio control and not just a free-flight model fitted with radio.

A common mistake made by modellers turning to single-channel radio control is to regard the model as a free-flight model for trimming purposes. The result is that the model is over-elevated for successful radio control, with the effect of making it prone to zoom or even stall every time rudder control is released and the model automatically recovers to its "straight" flying trim. This makes it very much more difficult to control than a model which is under-elevated by free-flight trimming standards. However, unless the design is suitable for rudder-only control, under-elevation can make it difficult to perform turns without losing a lot of height.

A lot more can be done than just turns with rudder-only control. The spiral dive produced by holding on rudder is a manoeuvre (not to be confused with a true spin) and can be used to lose height rapidly. The model will also increase its speed considerably in a spiral dive and when control is released at the end of the spiral dive it may well have enough speed on straightening out to perform a loop. It is also possible to lose height by performing a fairly violent S-turn. Thus rudder-only does provide the possibility of control in both direction and height. With practice—and a suitable design—it may also be capable of producing other manoeuvres, such as a form of flick roll (model allowed to zoom after a spiral dive and then rudder held on at the appropriate moment to force the model into a roll).

In general, however, rudder-only control is at a distinct disadvantage when there is any appreciable wind, since most of the time control has to be directed at keeping the model heading into the wind. Any complete turn or other manoeuvre will result in a considerable drift of the model downwind. About the only way to overcome this is to have a heavily loaded, fast-flying model which can penetrate upwind, but that usually means a model which is much more tricky to control.

The addition of motor speed control (via a compound actuator and secondary actuator) does offer improved control over height. To lose height the engine can be signalled to "low" speed, but again the same limitation as above applies in windy weather. The addition of elevator control via a "kick" action on the actuator does provide further possibilities; making either an "up" elevator position available for performing loops; or a "down" elevator position for putting the model into a straight shallow dive to lose height. A "down" elevator control is also useful in correcting "zoom" after a turn.

Motor speed control and (one) elevator position can both be made available off a single compound actuator and two secondary actuators, and will give even more control. This means, however, *four* signalling positions and needs considerably more practice to master. It will be appreciated from the above that the main control (rudder) is used frequently and usually rapidly, and unless it can be selected simply control may be lost. Too many "sequence" positions for switching make the system impractical to operate. That is why the most satisfactory system with single-channel is usually rudder-only plus "quick blip" engine speed changeover or a trip elevator position (again preferably selected by "quick blip").

It will be appreciated also that successful single-channel radio control demands a model design which has a good degree of normal free-flight stability to recover on its own when the rudder control is centralized. It is not suitable for models which have very limited free-flight stability, such as low-wing scale models.

To gain more control it is necessary to go to multi-channel working. In fact, if it were not for the additional expense, multi-channel working would be better even for just rudder-only, for it would enable either right or left rudder positions to be selected immediately and positively, using two channels. This is borne out in practice. Any rudder-only design can be flown better on two-channel radio than on single-channel. Having gone to the expense of multi-channel equipment, though, it is pointless to stop with rudder-only, unless the model is too small to accommodate additional equipment.

As noted in Chapter 2, conventional multi-channel operation is based on using two channels for direct signalling to one actuator, every pair of channels and its attendant actuator providing a separate control service. Thus multi-channel equipment can be considered in two-stage steps, i.e. 2-channel, 4-channel, 6-channel, 8-channel, 10-channel and 12-channel (the maximum practical with reed equipment).

For complete control of a model aeroplane in flight it is necessary to have directly signalled controls for rudder, elevators, engine speed (throttle) and ailerons. This means that 8-channel multi is needed.

A most significant feature now arises. With complete control it is no longer necessary that the model design has automatic stability. In fact, for maximum manoeuvrability and best control response it would be desirable that the model have more or less neutral stability so that it will continue flying on whatever line it is put by prior movement of the

controls. Hence the true "multi" aircraft design is quite different from the rudder-only design. A low-wing rather than a high-wing layout is usually preferred for a start; also dihedral is greatly reduced—see Fig. 5.2. The complete control available also makes the low-wing flying scale model a practical proposition.

Satisfactory performance, however, still depends a lot on trimming the model initially for "neutral" characteristics. If this is not done this will mean that one control or other may have to be used more or less continuously for correction—e.g. to correct a natural tendency to turn in one direction, or a natural tendency to go into a shallow climb or dive. Turning can be trimmed out by adjusting the engine thrust line offset (sidethrust). A diving or climbing tendency may or may not be capable of elimination by trim.

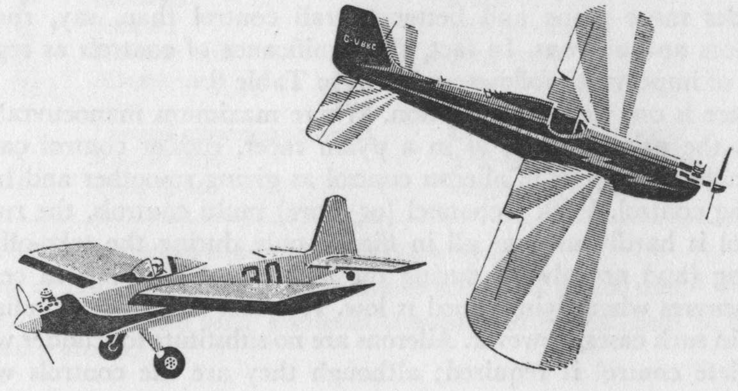


Fig. 5.2.

It therefore helps a lot to have one additional trim control for elevators, calling for 10-channel equipment. This will also make for smoother flying. An additional trim control on rudder (or ailerons) is not essential, although many modellers feel that it is justified with the availability of 12-channel equipment. Alternatively it may be more advantageous to use the additional two channels for other useful services, such as retracting the undercarriage, or operating wing flaps.

Apart from increasing cost with additional channels in use, the weight and bulk of equipment also goes up with every additional two channels utilized. This in turn demands a larger model and, in particular, a more powerful engine. To some extent, therefore, the number of channels used is dependent on model size, although not to the same extent as previously, since modern "multi" servos are quite compact.

The so-called "intermediate" model has a considerable following because it allows a medium-size model to be used and reduces the cost of radio equipment by employing only six channels. The services then selected are normally rudder, elevators and engine speed control. This provides more scope and better overall control than, say, rudder, elevators and ailerons. In fact, the significance of controls as regards order of importance follows as shown in Table 6.

There is one notable exception. Where maximum manoeuvrability is not the primary aim, as in a pylon racer, rudder control can be eliminated in favour of aileron control as giving smoother and better turning control. With 8-channel (or more) multi controls, the rudder control is hardly used at all in flight—only during the take-off and landing (and not always during the latter) and at points in certain manoeuvres when flying speed is low. It is still regarded as indispensable in such cases, however. Ailerons are no substitute for rudder where complete control is required; although they are the controls which would always normally be used for making turns once airborne.

Another possible way of extending services is by coupled controls. This enables one "command" to operate two controls simultaneously, providing additional controls without having to increase the number of channels. Coupling may be electronic or purely mechanical, depending on the services involved—see Table 7.

Electronic coupling is usually applied only to ailerons and rudder. Both controls are operated by separate servos but these servos are connected in parallel to the same pair of reeds. Thus signalling "rudder" produces a corresponding movement of the ailerons—Fig. 5.3. This is not the same as being able to signal ailerons and rudder separately, but it does provide aileron control for turns and improved manoeuvrability as a consequence. In some manoeuvres, however, the fact that the rudder always moves with the ailerons, and vice versa, can be a disadvantage.

Table 6

ORDER OF IMPORTANCE OF AIRCRAFT CONTROLS

Order	*Control*	*Type of movement**
1	Rudder	self-neutralizing
2	Motor speed	progressive (or changeover)
3	Elevators	self-neutralizing
4	Ailerons	self-neutralizing
5	Elevator trim	progressive
6	Aileron trim	progressive
	or	
	Limited-movement ailerons	self-neutralizing
7	Rudder trim	progressive (see Note 1)
8	Wing flaps	progressive (see Note 2)

* With single-channel or conventional multi-channel.

Note 1: This would not normally be used in addition to aileron trim.

Note 2: Rather than using additional channels, this control could be coupled to another service.

Selection of controls

Using this table, allocation of services should follow in order according to the number of control channels available. For example, with single-channel and a compound actuator giving an additional service, normal choice would be (1) rudder and (2) motor speed. With 6-channel "multi", normal choice would be (1) rudder, (2) engine speed and (3) elevators; and so on. See also Table 7.

This particular system can be improved by incorporating an "uncoupling" feature, aimed at uncoupling the rudder servo from the paralleled circuit with the aileron servo. Thus rudder control will be required only at low speeds, and to be effective at such speeds a fairly generous rudder movement is required. This could induce unwanted yawing effects at higher speeds if coupled to the ailerons. If the rudder servo is wired through a pair of contacts which are closed only when the engine throttle is at slow speed position, rudder control will be available

Table 7

COUPLED CONTROLS

	Coupling	
Controls	*Mechanical*	*Electronic*
Aileron-rudder	Possible but not recommended*	Aileron and rudder servos connected in parallel
Nosewheel steering	Linked to rudder servo	—
Tailwheel steering	Linked to rudder movement	—
Wheel brakes	Operated by full "up" elevator movement	—
Flaps	—	Separate servo switched by a particular main control position

* Because "uncoupling" is not possible.

only at low speeds (coupled to ailerons). At all other engine speeds, with the throttle advanced and opening the rudder circuit, the rudder servo will be uncoupled and only the aileron servo will be working on this circuit. In practice the contacts would not be located adjacent to the throttle arm, as shown in this diagram, but internally where they are protected from engine exhaust, and operated directly by the rudder servo movement.

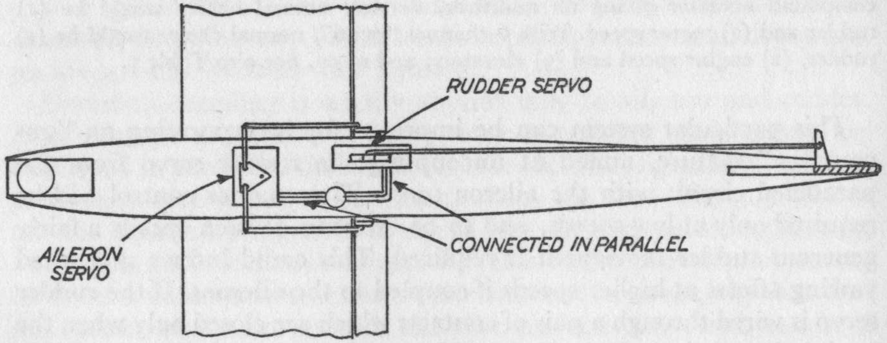


Fig. 5.3.

There are other methods of uncoupling. One alternative is to provide rudder over the full engine speed range but still have decoupling; the decoupling switch can be arranged so that it is opened at extreme "full" throttle position and closed in all other throttle positions. Full throttle is thus selected when decoupling is required (i.e. ailerons only signalled by that particular key). Backing off the throttle a little will couple in the rudder control to the ailerons—Fig. 5.4. There will actually be very little reduction in engine speed, if any, and so rudder is now available over virtually the full speed range (coupled to ailerons).

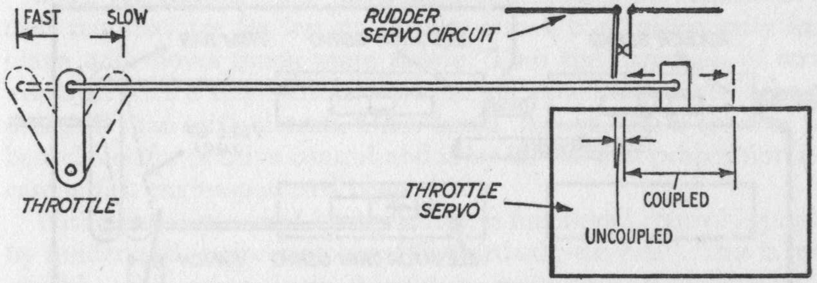


Fig. 5.4.

Yet another possibility is to operate the coupling switch by the elevator trim movement so that full "up" trim gives coupled ailerons and rudder (a trim condition where rudder control is most likely to be required). Once the elevator is eased off, full "up" trim position, the rudder servo is uncoupled and only ailerons are available from that particular control channel—Fig. 5.5. This is probably the best method of using coupled-aileron and rudder with 8-channel "multi" equipment to give a performance comparable with 10 channels. Decoupling via throttle movement may be more effective when using proportional controls with a limited range of coverage, i.e. 3 + 1 (see Chapter 13).

Decoupling, in this manner, virtually gives the same control facilities as two additional channels as far as the transmitter–receiver combination is concerned; but it does not save the cost of an additional servo. Its chief application, therefore, would be to extend the facilities of 6-channel equipment to 8-channel equivalent; or 8-channel equipment to 10-channel equivalent. It is equally applicable to other controls which could be paralleled and one of which is required under particular conditions—e.g. flaps only required with, say, low engine speed.

Mechanical coupling can be applied to secondary services which can operate simultaneously with a main control without affecting performance. Thus for ground manoeuvring a steerable nosewheel (or tailwheel) can be operated directly by a linkage from the rudder servo. Wheel brakes can be operated by "up" elevator position by mechanical linkage to the elevator servo. These are the two main secondary services which improve the functional performance of the model.

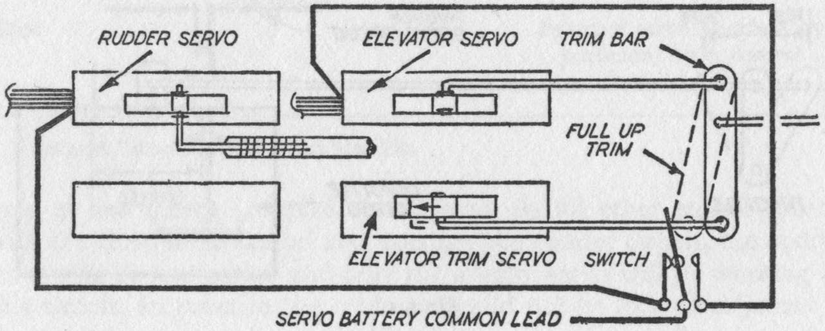


Fig. 5.5.

All the control systems discussed, in fact, have been based on functional requirements aimed at increasing the scope of overall control to give the best possible flying and handling performance. Where the modeller is not so concerned with a fully aerobatic performance he may well prefer to eliminate some functional controls in favour of others, such as camera triggering and rewind for aerial photography; bomb dropping in flight; and so on.

Gliders are fully controllable on six channels (rudder, elevator and ailerons) and may well be satisfactorily controllable on less. Thus rudder and elevator may be adequate, both for tow-launched gliders and hand-launched sailplanes for slope soaring. In order to avoid loss of height, ailerons are by far the best control for turns, and elevator control is really essential. The best combination would provide for ailerons and elevator trim, plus normal elevator control for height control and rudder (for more powerful directional control when necessary).

Again similar considerations apply as for power models, although radio control gliders as a rule are generally designed with good free-flight stability to relieve the pilot of having to fly the model all the time. Even with rudder-only, two-channel multi will give better control than single-channel; and only multi-channel equipment will give complete control.

Boats represent a quite different problem since the functional controls required are far less numerous; also a boat moves only in one plane and moves much more slowly. Thus the extension of services available with a single-channel system via added sequences is far more practical than with aircraft. Once again, though, multi-channel is the best choice for positive control and is by far the best proposition in the case of fast engine-powered boats.

With electric-powered boats, complete functional control is provided by rudder and engine switching "forward-stop-reverse". This is readily possible with either single-channel or multi-channel equipment—see Table 8. With engine-powered boats four-channel multi is required for complete control, two channels operating the rudder and the other two controlling the engine throttle via a "progressive" type servo exactly as with aircraft.

Yachts also need four-channel equipment as a minimum for complete control. Two channels are then used for controlling rudder and the other two for controlling the sail settings. Here it is generally satisfactory to arrange to haul in or let out both the main and jib sheets from a single winch controlled by the "sail setting" servo; although sheets could be handled independently by going to two additional channels (see Chapter 11).

Once again these descriptions have been concerned with functional controls as directly affecting the performance of the model. With scale-type boats, in particular, one of the great attractions of radio control is to be able to operate realistic secondary services, such as lowering and raising the anchor, operating lights, lowering lifeboats, and so on.

Such ancillary services can usually be controlled satisfactorily through single channels; and also selected by sequence switching if necessary further to reduce the number of radio channels required. Thus individual "spare" channels (i.e. left over from functional control requirements) on "multi" equipment can be used to operate single-channel actuators or sequence switchers controlling the ancillary services. In this way a large number of services can be utilized, still keeping the number of radio channels required to 6 or possibly 8. Even single-channel can be extended to numerous ancillary services via sequence switching, only here it is important to retain reasonably direct access to the main functional control positions, i.e. not include them amongst a number of sequence positions. See also Chapter 7 and 11.

Table 8

ORDER OF IMPORTANCE OF BOAT CONTROLS

Order	*Power Boats*		*Yachts*
	Electric	*Diesel*	
1	Rudder*	Rudder†	Rudder‡
2	Motor forward—stop—reverse	Motor speed	Sail setting
3	Non-functional controls	Non-functional controls	Rudder trim
4	—	—	Non-functional controls

Note *: "Bang-bang" or progressive controls feasible.

Note †: "Bang-bang" control preferred, but proportional best. Progressive action feasible with a slow actuator.

Note ‡: Trim action (progressive) may be best.

Hovercraft are a specific type of model which also lend themselves to radio control, although the requirements are quite different from either aircraft or boats. Hovercraft of a size suitable for lifting the weight of a radio control installation are invariably engine-powered and so engine speed is a logical control. This will enable the model to be stopped at any time by throttling back the engine, and also lifted on to its air cushion by opening the engine throttle to full speed. Only these two speeds are required, so a changeover throttle control only is required, which can be operated by a single channel.

A hovercraft cannot be steered by a rudder like an aircraft. For one thing the rudder will be effective only if the model has a fair forward speed and even then application of the rudder will not turn the model so much as put it into a spin about its own axis.

The most effective steering control for hovercraft is usually two ducts, which may also be propulsion ducts, controlled by pivoted flaps as shown in Fig. 5.6. Thus to turn right the right duct is closed causing the model to pivot to the right. Control is then released, i.e. the duct opened, when it may be necessary to open the left duct momentarily to correct a tendency to overswing. With two channels allocated to steering control this technique is easily mastered with practice since each "turn" control can be signalled immediately and directly. With single-channel operation where "turn" controls have to be signalled in sequence the resulting delay (and the necessity to pass through an "unwanted" position) can make the system less suitable in practice.

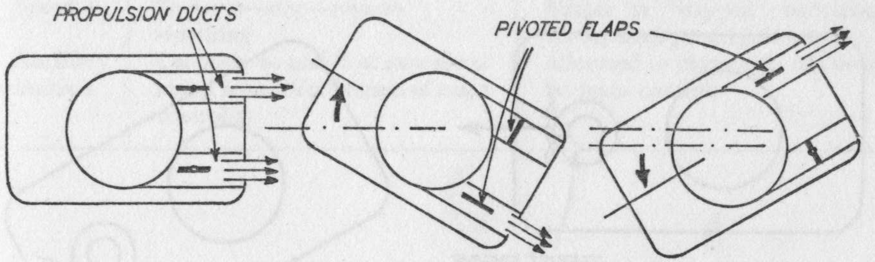


Fig. 5.6.

In this case an alternative is to use a separate small engine for propulsion, driving a conventional airscrew. This engine is mounted on a vertical pivot so that it can be turned from side to side, when the model will naturally follow the direction in which the thrust is pointed—

Fig. 5.7. The steering control actuator provides this turning motion. This is suitable for both single-channel and multi operation.

Model cars and similar vehicles do not lend themselves to specific control systems. Usually the necessary actuators are adapted to suit a particular model. Thus each model tends to be very much a "one off" job, the success of which depends largely on the skill of the individual builder, although certain basic recommendations apply—see Table 9.

Electric motor drive is usually employed on such models, when speed control can readily be obtained by switching the motor circuit—e.g. "on/off-reverse" for a simple solution; or through "stepped" speed positions like model boat controls (see Chapter 7).

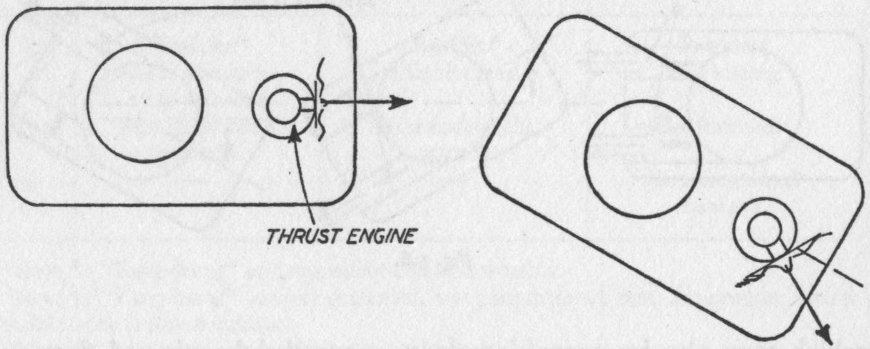


Fig. 5.7.

Steering control can be provided by a conventional motorized actuator working directly on the steering linkage, but this demands a reasonable size of model to accommodate the actuator. The great attraction with cars is to incorporate the control system within a minimum size of body, which usually means adapting a small electric motor as an actuator, operating the steering via a worm reduction gear. Multi-channel control is practically essential for good control when the steering motor can be operated progressively. Self-centring is not an essential feature for the successful operation of models of this type. Proportional controls are, of course, even better, but must be of a kind that give steady control positions, e.g. not the simpler systems which give "proportional" response from a control which is continually oscillating from side to side.

Table 9

MODEL VEHICLE CONTROLS

Control	*Single-channel*	*Multi-channel*
Steering	"Bang-bang" with motorized actuator	Electric motor or progressive servo
Speed	Forward—stop—reverse switching	Simple or "stepped" switching via separate progressive servo
Ancillary controls	Can only be added at expense of losing some effectiveness of main control(s)	Allocated to channel(s) not used for main controls

CHAPTER 6

SINGLE-CHANNEL INSTALLATIONS—AIRCRAFT

A SINGLE CHANNEL installation for rudder-only control comprises (i) a receiver; (ii) a suitable self-neutralizing actuator; (iii) a single battery in the case of relayless receivers, or separate batteries for the receiver and actuator in the case of relay receivers; (iv) wiring to complete the receiver-actuator-battery electrical circuit; and (v) mechanical linkage connecting the output of the actuator to the rudder.

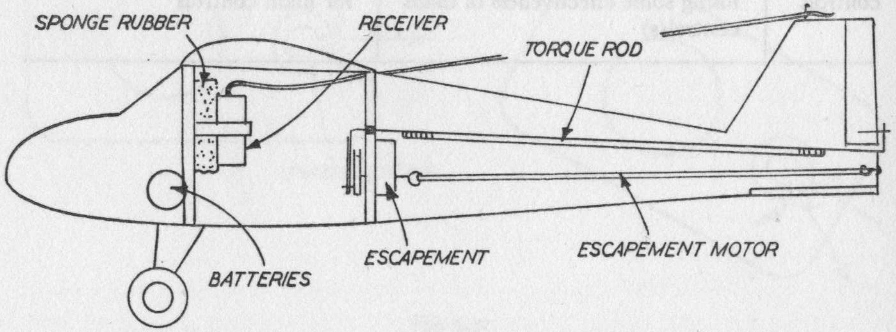


Fig. 6.1.

The major components involved—receiver, batteries and actuator—are best grouped together in the main part of the fuselage—Fig. 6.1. This places these weights to be carried in a position least likely to affect the trim of the model and also reduces the length of wiring required. This latter point is important, for minimum wiring length also reduces the resistance of the wiring in circuit and thus minimizes loss of voltage. On the other hand the wiring must be slack rather than tight, for reasons previously described.

The actuator is normally an escapement type and is best mounted on a main bulkhead at the after end of the "cabin" area or equivalent bulkhead position where the model does not have a cabin. Escapements are usually fitted with a Paxolin mounting plate, drilled with holes for mounting screws; this plate also carries terminal tags for the connecting leads. The bulkhead must be cut out to accept the shape of the actuator body so that it can be mounted with the rubber hook facing aft, as shown in Fig. 6.2. The mounting plate and crank arm which provides the mechanical output will then come on the front side of the bulkhead.

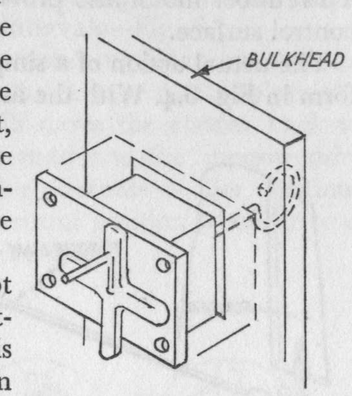


Fig. 6.2.

Except for very small models it is not satisfactory to bolt the escapement mounting plate directly to a balsa bulkhead. It is better to mount the escapement on a thin ply plate which is then cemented in position to the balsa bulkhead. Both the ply plate and bulkhead have cut-outs to accommodate the escapement, the latter cut-out being large enough to clear movement of the escapement arm. Alternatively, the escapement can be mounted on a ply plate which is then securely cemented across the fuselage rather than to a specific bulkhead—Fig. 6.3.

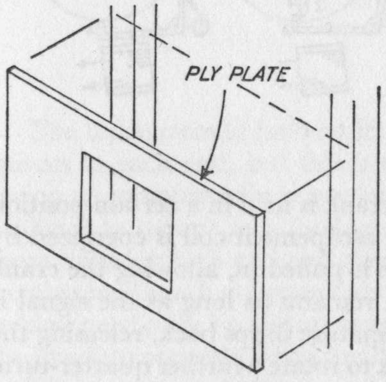


Fig. 6.3.

The main thing is to get a secure fastening for the actuator on a flat surface, taking particular care that it is not distorted in any way, as this could interfere with its accuracy or working. Small machine screws (6 BA or 8 BA) should be used for mounting rather than woodscrews and the nuts locked against vibration, using locknuts or double nuts, soldering, or coating with thread-locking cement.

The mechanical output of an escapement is invariably provided by a crank arm or crank pin which rotates a quarter of a turn at a time when released by movement of the pivoted armature. Power to produce this rotation is provided by a simple rubber motor attached to the hook on the escapement spindle. This rubber motor also provides the mechanical power for moving the control surface.

The actual action of a simple escapement is shown, in diagrammatic form in Fig. 6.4. With the armature in its normal position (no current flowing through the actuator coil) the crank is held in a certain position corresponding to "neutral". When the escapement coil is energized by a signal from the receiver the armature is pulled in, allowing the crank to rotate a quarter of a turn, where it remains as long as the signal is held on. On release of the signal the armature drops back, releasing the escapement arm and allowing the crank to rotate a further quarter-turn. This brings it back to the "neutral" position once again. The *next* signal then allows the crank to rotate another quarter-turn, or to the opposite side it assumed after the *first* signal. On release of signal it rotates a quarter of a turn again to bring it back to the "neutral" position.

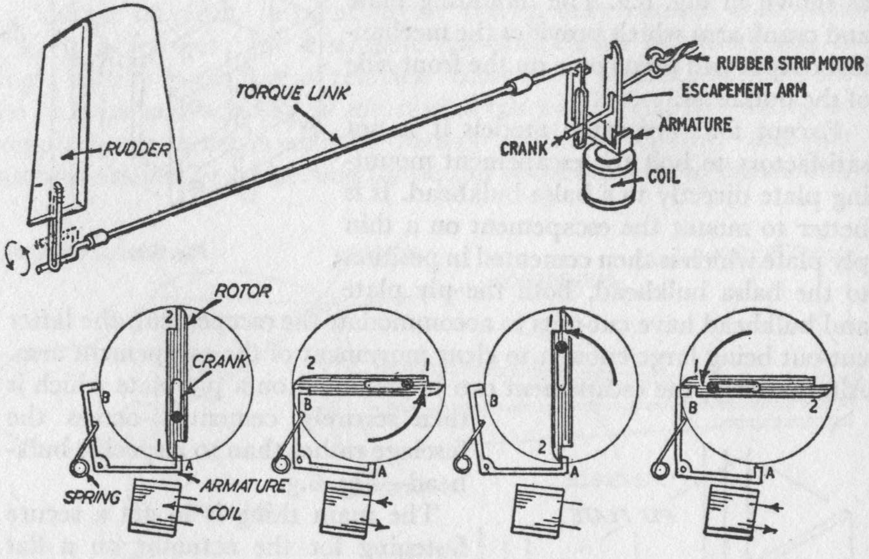


Fig. 6.4.

Modern escapements are normally of the four-arm type. These have an identical quarter-turn action, the main reason for using a cruciform arm instead of a straight arm being that only a single detent is needed to trip and stop rotation at quarter-turn intervals—Fig. 6.5.

Allied to a suitable mechanical linkage, as shown, this means that the first signal will allow the crank to drive the linkage and displace the rudder to one side. Release of signal will move the rudder back to neutral. The second signal will move the rudder to the opposite side, and so on. Thus successive signals will give alternate rudder positions and the rudder will always return to its neutral position when there is no signal, i.e. the escapement coil is not energized.

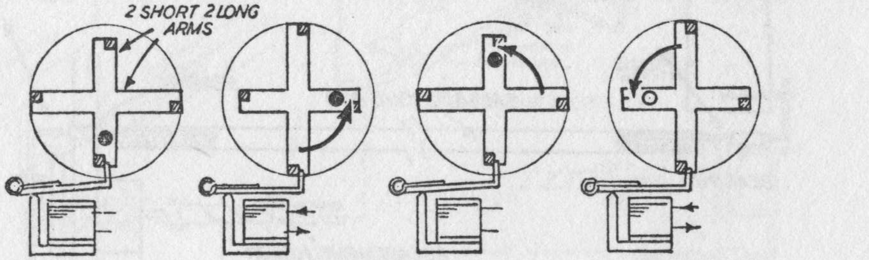


Fig. 6.5.

The linkage could be bent from a single length of wire, supported on pivots at each end, but this is seldom a practical solution. It involves using an unnecessarily heavy length of wire for a start. Also it would be difficult to mount in a fuselage. The best method is to make separate wire links for each end and then join by binding to a length of square-section medium-hard grain balsa Fig. 6.6. Each link has its own bearing, which need only be a short length of metal tube and the assembly can be lined up properly when finally binding the balsa torque rod in place.

The only critical part in such an assembly is the front wire link. The end fitting over the escapement crank pin needs to be in the form of a loop long enough to accommodate the full "up-and-down" movement of the crank pin so that the escapement arm can rotate without jamming. It must also be a snug enough fit so that free movement is reduced to a minimum, otherwise the rudder could flap about.

The loads carried by the linkage are not high, so fairly thin wire can be used which will make it easier to produce accurate bends. Steel wire of 20 s.w.g. is quite adequate for small and medium-size models. 18 s.w.g. wire would be used for larger models. The balsa torque rod can be $\frac{3}{16}''$ square for small models; $\frac{1}{4}''$ square for medium-size models and $\frac{3}{8}''$ square for large models.

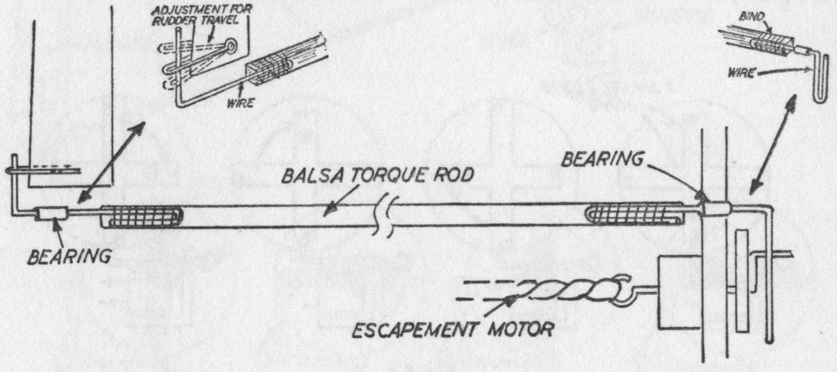


Fig. 6.6.

The rudder end linkage is extremely simple, merely reproducing the motion of the escapement in another cranked fitting which slides in a wire loop bound to the rudder. The proportions of this end crank and loop govern the actual amount of rudder movement produced. In practice this can be made adjustable by bending the loop to alter the movement arm—see Fig. 6.6. Note also the alternative end fitting designs shown in Fig. 6.7, although the simple 90-degree bent crank and loop is quite adequate and usually preferred. However, this will give left rudder as the first position (i.e. for the first signal) unless the linkage is taken below the escapement—see Fig. 6.7. Standard practice is to arrange for the *first* signal in a sequence to give *right* rudder. Escapement will only work one way round (normally anti-clockwise rotation when viewed from the crank end, consistent with the conventional way of winding up a rubber motor in a clockwise direction).

It is not essential to arrange that the first signal gives right rudder, but by adopting this as standard it does mean that all rudder-only models will have a similar response. Control becomes more or less a matter of automatic reaction with practice, but to handle an "opposite hand" model with regard to rudder sequence would need additional practice.

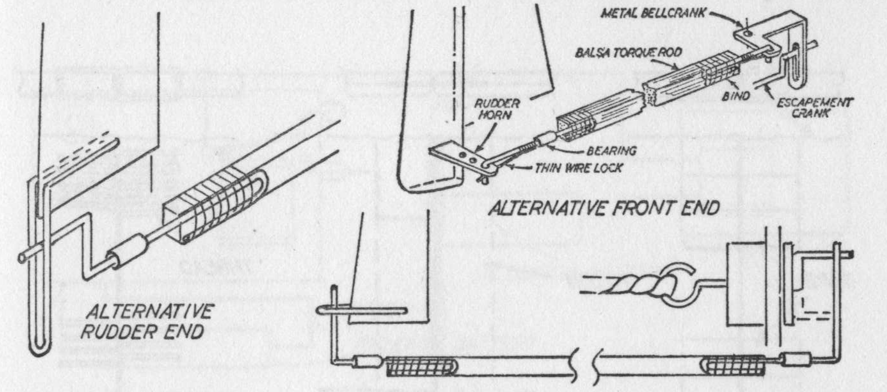


Fig. 6.7.

On medium- to large-size models a different form of linkage is sometimes preferred, connecting the escapement crank to a bellcrank which then provides a push-pull output to operate the rudder, as shown in Fig. 6.7 (top right). The pushrod can again be balsa strip with bound-on wire end fittings, or commercial linkage units may be used with adjustable end fittings. These have the advantage of permitting exact adjustment of rudder relative to the linkage. With simple systems the adjustment required (to get the rudder in a true neutral position) is usually made by bending one or other of the wire fittings. The bellcrank system with push-pull output is a more positive mechanical linkage but will usually have higher friction. It is therefore more suitable for use with motorized actuators rather than escapements.

The operating force available with escapements is quite small since the rubber motor is usually limited to a single loop (2 strands) of $\frac{3}{16}''$ strip rubber, or perhaps only $\frac{1}{8}''$ strip in the case of miniature escapements. The power of the rubber motor cannot be increased by increasing the number of strands, as the resulting additional tension could distort the escapement. Thus the recommended rubber size for the escapement must not be exceeded. It is also important that the rubber motor should run in line with the escapement spindle, again to avoid side loads on the rather delicate mechanism and the possibility of distortion. With restricted power available from the rubber motor it also follows that the linkage should be well and accurately made with a minimum of friction opposing movement.

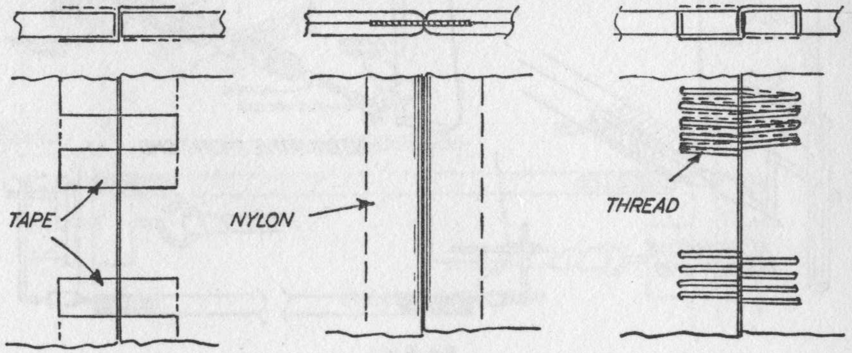


Fig. 6.8.

It is also important that the rudder be freely hinged. A variety of rudder hinges are shown in Fig. 6.8. The tape hinge, as commonly used on control-line model elevators, is popular, but can be rather stiff. Thread hinges are excellent but not very neat. Wire pivot hinges have the least friction, if properly made, and also permit a certain amount of the rudder to overhang the hinge line to provide aerodynamic balance. This relieves the escapement of a certain proportion of the effort needed to turn the rudder to its "right" or "left" position. A balanced rudder is generally to be recommended on larger models when powered by

escapements. Rudder balance is not necessary, however, where the rudder is operated by a motorized actuator.

Batteries and receiver are usually located close together in the main section of the fuselage, the batteries preferably being placed in front of the receiver—often in a separate compartment on the forward size of the front cabin bulkhead. If DEACs, the battery can be permanently installed. If dry batteries, provision must be made for removing and replacing the batteries. The receiver can be mounted simply by wrapping round with a vibration insulating material and pushing into a suitable box-type compartment. There is no need to fasten it in place other than to make sure that it cannot shift its position, and in no circumstance should it be rigidly mounted to the fuselage. Horsehair-type packing is to be preferred for insulation packing, although foam plastic is a more readily available alternative.

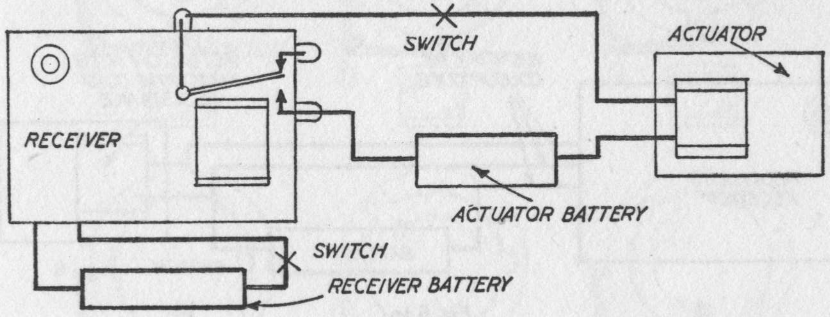


Fig. 6.9.

A typical wiring diagram for a relay type receiver is shown in Fig. 6.9. This is common to all types and the wiring is always the same for all receivers which work on a "current rise" principle (i.e. all tone receivers). Carrier receivers normally work on a "current fall" principle, in which case the opposite relay contact is used for connection.

With relayless receivers the receiver has an additional number of connections which are specific to the circuit involved, i.e. the actual design of receiver. These leads are normally ready fitted to the receiver and identified by colour. Wiring up must then follow exactly the instructions given for that receiver. Fig. 6.10 is a typical wiring circuit and it will be appreciated that there is no real identification of the switching circuit, as with relay receivers, except by the colour code specified for the receiver wires. Specific instructions may also apply to the escapement where this is of the compound type and has more than two terminals (i.e. additional switching terminals as well as the escapement coil terminals).

Both wiring circuits must include an on/off switch for the battery. In the case of relay receivers this should be of the double-pole type so that both the receiver and servo batteries can be switched on and off, or separate switches used in each battery circuit. Although the relay contacts act as a switch for the servo battery circuit these cannot be relied upon completely to isolate this circuit when not in use.

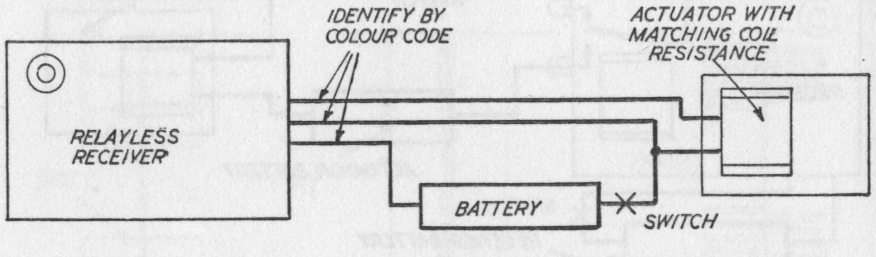


Fig. 6.10

The amount of wiring involved is quite small and individual wires can be left "floating" between their end connections, with a reasonable amount of slack. For neatness they can be "cabled" together by binding at intervals with insulation tape, if preferred. Positive anchoring of wires to the switch and escapement is recommended, as described in Chapter 3. If "cabling" is done, then *always omit the aerial wire from such cabling*. This should always run as a separate wire, preferably taken outside the fuselage at a point near the receiver and then either strung back to the top of the fin, or cemented along the underside of the fuselage. Any excess length of aerial should then be left to trail free.

The aerial wire should not be cut off as this is normally a tuned length selected to match the receiver circuit to give optimum performance.

Where additional services are to be operated on a single-channel system this calls for the use of a compound actuator and an additional (secondary) escapement. The main control system and wiring is the same as before. The secondary actuator then requires its own linkage to operate the second control, and its own separate wiring to the main escapement or actuator.

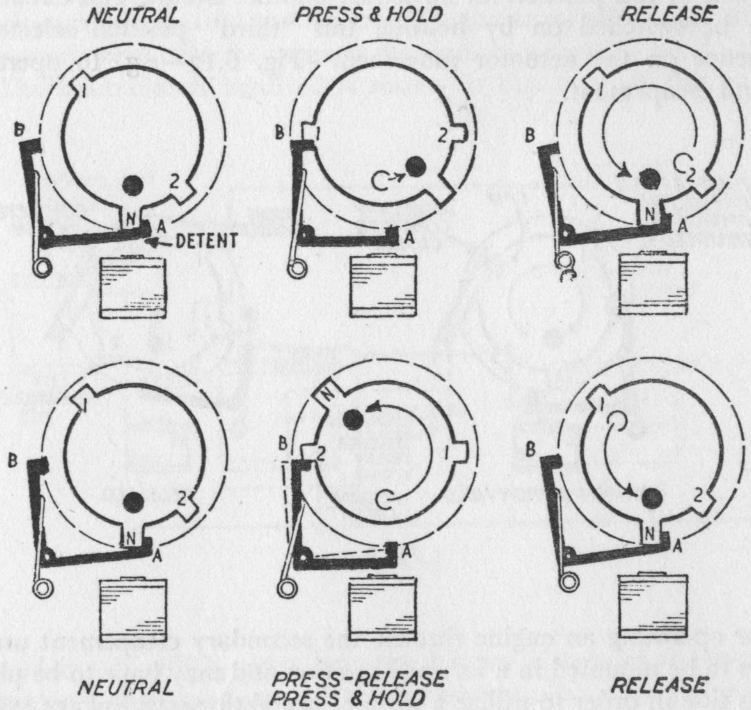


Fig. 6.11.

Compound escapement action is shown in Fig. 6.11. In addition to the two normal "stop" or hold positions, a third position "stop" is provided which again can be selected in sequence. This is placed so that the crank or crankpin is in a nearly neutral position, so that effectively the main control is neutral.

Rather than use this third "hold" position for providing a mechanical output, however, it is usually more practical to close a pair of electrical contacts at this position for switching another circuit. This circuit can then be switched on by holding this "third" position selected in sequence on the actuator movement—Fig. 6.12—e.g. to operate a second escapement.

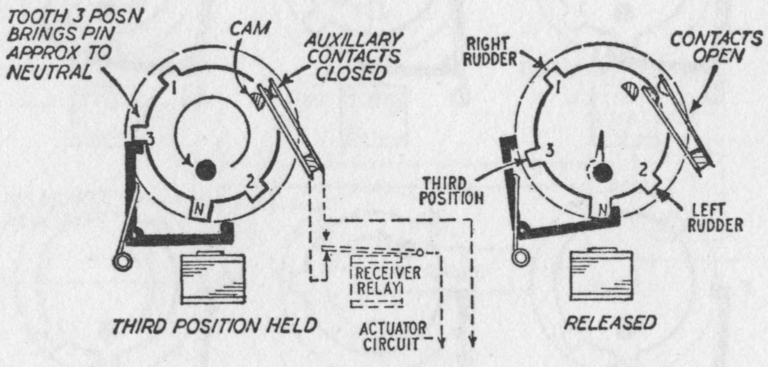


Fig. 6.12.

For operating an engine throttle the secondary escapement usually needs to be mounted in a forward position and may have to be placed on its side in order to utilize a simple, straightforward linkage system. This can seriously restrict the length of rubber motor which can be used on the secondary escapement. If there is room, it may be better to adopt the bellcrank linkage of Fig. 6.7 to permit the secondary escapement to be mounted the right way round. Alternatively an escapement driven by clockwork is sometimes used for motor speed control since this does not require a rubber motor.

With the main actuator of compound type providing switching for the secondary escapement from built-in electrical contacts additional wiring is required to the actuator contact terminals. To operate with

a relayless receiver the secondary switching circuit must be built into the actuator (usually on a printed circuit panel) when it is only a case of (i) making sure that the actuator selected is suitable for matching a relayless receiver; and (ii) following exactly the wiring-up instructions supplied with the actuator. With a relay receiver switching connections on a compound actuator need one lead to be wired back through the receiver relay to avoid the secondary actuator switching circuit being triggered every time the receiver responds to a signal.

The basic circuit involved is shown in Fig. 6.13. If this circuit is traced out it will be seen that the battery circuit to the secondary actuator is completed only when the receiver relay is being held in (in response to a signal) and the actuator has moved to the "third position" which closes the secondary actuator switching contacts. If the signal is not held on, but the actuator is merely rotating after being released from a previous signal, the relay contacts used on the secondary circuit are open. Thus although the secondary actuator contacts close when the actuator passes this position the secondary actuator circuit is still broken (by the relay contacts). Only when the "third position" is held by the signal are both sets of contacts closed to complete the circuit.

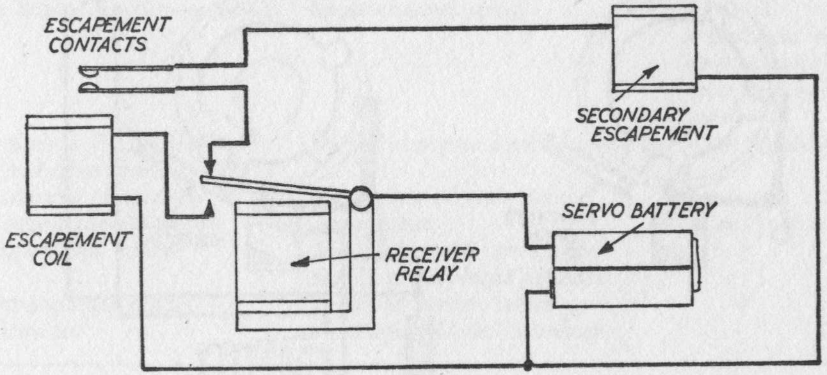


Fig. 6.13.

The same principle applies with "quick blip" switching, only in this case the secondary actuator contacts are closed by initial movement of the actuator "timed" to a quick blip signal with the relay dropping out to complete the circuit through the back contact—Fig. 6.14. With any other signal held on, or pulsed for normal sequence signalling of either one or other rudder position, the relay is held in at the point of rotation where the secondary actuator contacts are closed, and hence the circuit to the secondary actuator remains open.

Other variations on single-channel installations are built up on similar principles, with secondary actuators wired to the respective switching contacts on the main actuator. Both the main and secondary actuator(s) work off the same battery, although this imposes distinct limitations on extension of services with a relayless receiver where the output is usually matched to a single 8-ohm resistive load and may not be suitable for powering two actuators of this coil resistance together. Cascaded actuators demand specific interconnection of specially matched actuators, with built-in switching normally incorporated on the printed circuit panels of the two units; and also connecting them

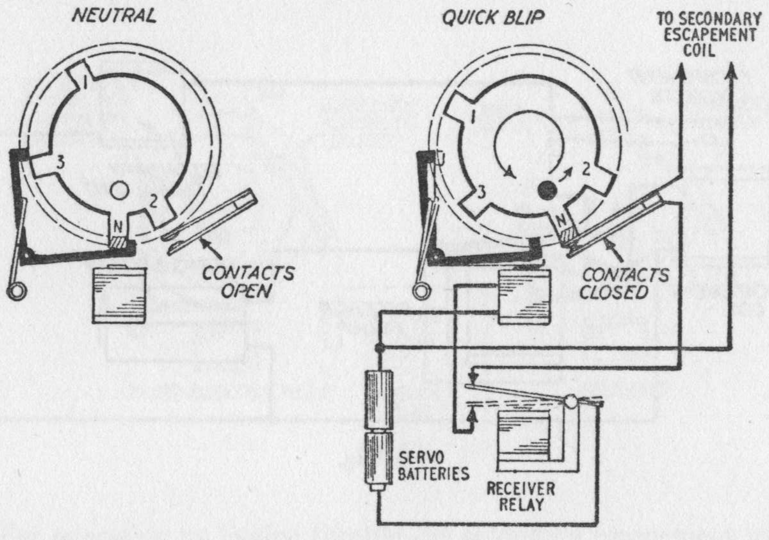


Fig. 6.14.

Table 10

PRACTICAL SINGLE-CHANNEL AIRCRAFT CONTROL SYSTEMS

Controls	*Main Actuator*	*Secondary Actuator*
Rudder only	S/N escapement	—
Rudder +		
(*a*) Engine speed changeover or	Compound S/N escapement or	(*a*) 2P or 4P escapement
(*b*) Engine speed 3—positions	single-channel servo	(*b*) 2P or 4P escapement or single-channel motorised actuator
Rudder + "kick" elevator + engine speed	Special compound escapement	As (*a*) or (*b*) above
Rudder + elevator + engine speed	Two cascaded compound escapements	As (*a*) or (*b*) above
Proportional rudder	Modified electric motor or simple proportional actuator	†
*Proportional rudder + elevator	Modified electric motor or "Galloping Ghost" actuator	†

* Requires use of pulser associated with transmitter.

† Switching contacts for motor speed may be available via a secondary actuator (see Chapter 9).

mechanically so that the wheel of one is mechanically linked to the other cascaded escapement—see Fig. 6.15, although both are powered by their own rubber motors.

Basically a single compound actuator of special design can provide switching for motor speed plus an additional mechanical output for one-way operation of a control, self-neutralizing on release of signal. This can provide a "kick" elevator control in addition to rudder and engine speed—Fig. 6.16. A pair of matched compound actuators in cascade can provide two fully sequenced mechanical outputs for rudder and elevator control respectively, plus switching for motor speed control. The two main controls—rudder and elevators—then come in the same sequence for signalling. Thus, for example, to repeat, say, one

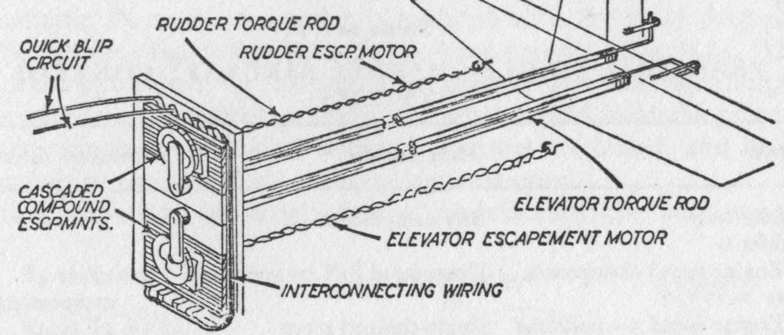


Fig. 6.15.

rudder position, the second position has to be signalled through a full sequence of rudder and elevator movements. As a consequence the system is much less direct and slower working, and there is a greater possibility of making an error in the signalled sequence.

The above, basically, covers all necessary requirements for single-channel aircraft installations with the exception of "bonding". Movement of one metallic part over another is capable of generating electrical "noise" which can interfere with the action of the receiver by

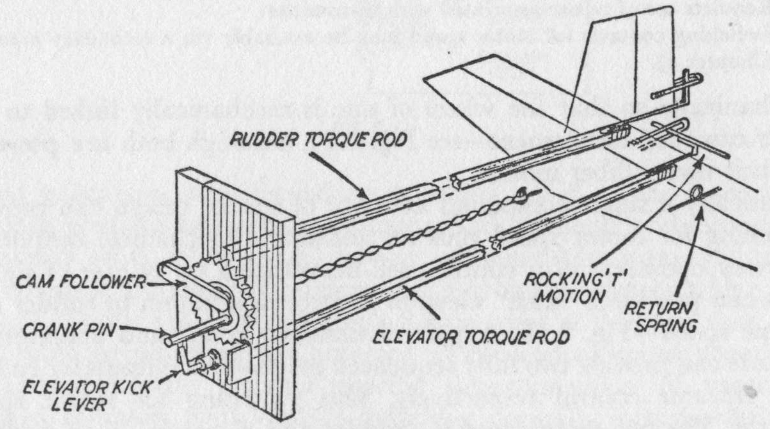


Fig. 6.16.

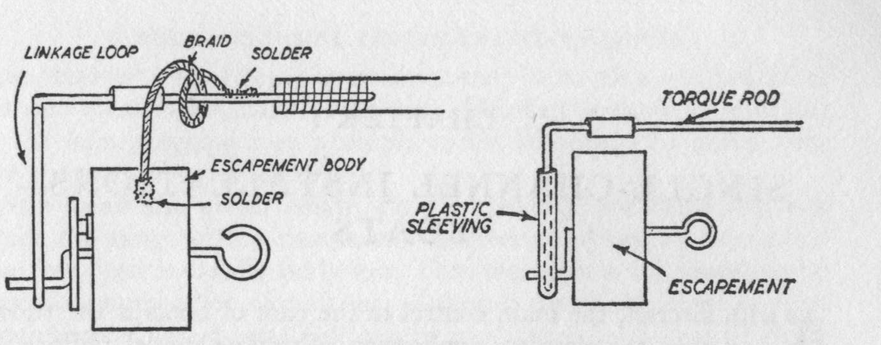


Fig. 6.17.

acting as spurious signals, particularly as receiver and actuator linkage are usually close together. This sort of intereference can be most marked with miniature receivers. It can be eliminated completely by electrically bonding the escapement body to the linkage by soldering a "pigtail" lead of flexible copper braid between the two as shown in Fig. 6.17. It is seldom likely to be necessary to bond the tail-end metallic linkages in this fashion, unless all-metal linkage is used throughout; and bonding may not be necessary at all in many installations. Since it is so simple to do, bonding is to be generally recommended with all escapement installations. Remember, however, it is only metal-to-metal rubbing joints which can generate "noise". Metal linkages connecting to nylon or plastic cranks or fittings are free from this phenomenon.

CHAPTER 7

SINGLE-CHANNEL INSTALLATIONS—BOATS

As with aircraft, the main control in the case of boats is the rudder and thus the simplest application of single-channel radio is for steering via a suitable actuator. Escapement-type actuators are not really suitable for boats since they do not have enough power to move a water rudder effectively; also it is awkward to accommodate the rubber motor necessary with an escapement in a boat hull. For small boat models a clockwork-type escapement can be used, i.e. similar to an ordinary escapement but powered by a clock-type spring rather than a rubber motor—but choice of actuator for marine work is normally a motorized unit or single-channel servo.

Basic installation requirements are the same as for aircraft, with the motorized actuator replacing the escapement, although the positioning of the various units is different. The receiver needs to be located in a protected region where it will be kept dry, and also as far away as possible from electric motors. Locating it well forward in the hull, as in Fig. 7.1 is recommended. The actuator is best fitted near the rudder to reduce control linkage to a minimum. The batteries can then be located at any convenient point between the receiver and actuator, using their weight to trim the model. If the boat is powered by an electric motor this will demand a fairly large and heavy battery for the drive motor when this and the radio batteries can be mounted together amidships.

Only the actuator needs to be rigidly mounted. The batteries can lay in a suitable box or compartment and the receiver can simply rest in a suitable box or carrier, wrapped in vibration-resistant packing. The receiver must be accessible for tuning, and the batteries must be accessible for replacement.

The aerial is a bit of a problem, for if the end is allowed to trail on a damp surface it will be "earthed" and rendered incapable of receiving signals. If the hull is long enough it can be permanently cemented in place to the underside of the deck (with a plug-and-socket connection to the receiver); but a better proposition may be to use a whip aerial of thin wire erected vertically on the deck. This can be made removable; i.e. the wire plugging into a simple socket to which the aerial wire from the receiver is soldered.

With boats the aerial length can be reduced. Although this will reduce the range of the transmitter–receiver combination the actual range required is usually fairly low. Thus although a 24″ to 30″ aerial length is common for aircraft use, a shorter length of aerial is often quite effective with boats. This can be established by an actual check with the equipment.

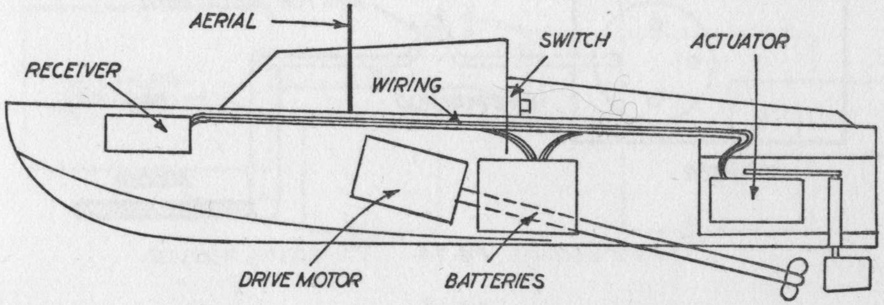


Fig. 7.1.

Unlike aircraft which follow a more or less standard layout for the various components, mounting positions are often selected more for convenience than anything else. Thus instead of the arrangement of Fig. 7.1 it may be more convenient to group receiver and actuator together in the same compartment, or under a hatch. Additional protection for the receiver may also be provided by wrapping it in a polythene bag, although this will make it difficult to reach the tuning control. This is an important feature, for a receiver can only be tuned properly with the boat in the water and the receiver installed (with its bag wrapping, if this is to be used). A short length of tuning wand bonded to the tuning slug and emerging from the receiver case can make the tuning control accessible by grasping through the bag.

The motorized actuator is, as the name suggests, powered by an electric motor. This drives its own built-in switching unit so that it performs like a conventional escapement, driving an output arm one quarter of a turn and stopping there on receipt of a signal; rotates another quarter-turn to a "neutral" position on release of signal, and so on. Mechanical linkage to drive the rudder is then simply as shown in Fig. 7.2, the actuator output providing a push-pull motion. Final adjustment for neutral rudder position can be made by bending the tiller arm, as necessary, or incorporating a kink in the push rod which can be closed or opened up slightly for adjustment.

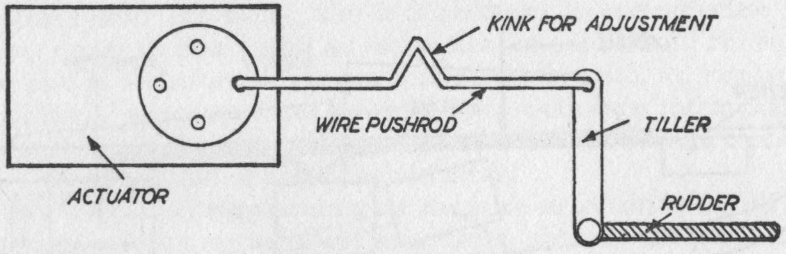


Fig. 7.2.

Note that motorized actuators are invariably geared down to provide a relatively slow-moving output. In other words although a motorized actuator is basically a specially switched electric motor the output speed of a normal motor is far too high to be applied directly to a control linkage. Motorized actuators, in fact, are generally slower in (output) action than escapements. This is a feature common to all types of motorized actuators; and boat-type actuators specifically made for boat controls may be slower than aircraft types. Special boat actuators may also be enclosed in fully waterproofed casings, which is a great advantage. Dampness is a common source of trouble with conventional motorized actuators used in boats.

Motorized actuators draw currents of the order of 500 milliamps or more. Depending on the design, the motor may either "switch off" when holding a control position, or continue to run and "hold" the control on via a slipping clutch. In either case the current drain is more

than a relayless receiver can usually provide direct from its own battery. For this reason a relay-type receiver is to be preferred; or if a relayless receiver is used this should be connected to a slave relay and the actuator circuit completed through the slave relay contacts and a separate battery for the actuator—Fig. 7.3.

The slave relay needs to have a coil resistance to match the relayless receiver output. Normally a matching output load is about 8 ohms, as applied to escapement coils. For a slave relay any coil resistance of from 10 to 50 ohms should prove satisfactory as the resulting current flow will be quite high enough to operate the relay consistently. The slave relay can be mounted virtually anywhere, but preferably near the actuator and reasonably remote from the receiver when it is less likely to cause interference.

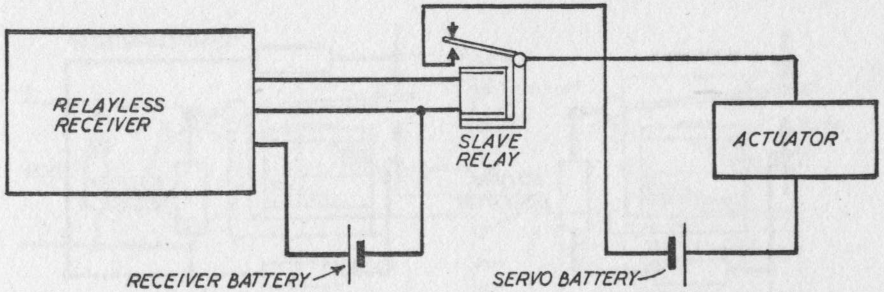


Fig. 7.3.

Both the actuator motor and the making and breaking of the relay contacts will produce electrical "noise" which could interfere with the receiver. In the case of a commercial actuator, suppression is invariably built into the motor circuit and thus no troubles should be experienced here, unless the receiver is of an extremely sensitive type and located very close to the actuator. Slave relay contacts can be suppressed, if necessary, by soldering a capacitor across the working contacts, as shown in Fig. 7.4.

If the main power unit of the boat is an electric motor this will certainly need suppression, and various methods of doing this are shown in Fig. 7.5. A single capacitor connected between the two motor terminals is usually adequate, although one capacitor on each motor terminal and earthed to the motor body may be more effective in some cases. In really bad cases of motor interference it may be necessary to use the more elaborate scheme shown employing two chokes (one in each motor lead) and two capacitors. A point to bear in mind when dealing with interference problems is that the simplest cure is to move the receiver as far away from the source of interference as possible. This will then make any suppression device much more effective.

Most single-channel servos are of compound type. That is, as well as giving sequence rudder positions with self-neutralizing action on release of signal, an additional one (or more) switching position(s) is included. Single-channel servos designed specifically for boat use may incorporate built-in switches which provide extra controls merely by connection to appropriate terminals on the servo circuit, e.g. complete built-in switching for motor forward-stop-reverse, in sequence. With other types, or other services required, it is necessary to use the additional switch position(s) to operate a further switcher and/or actuators.

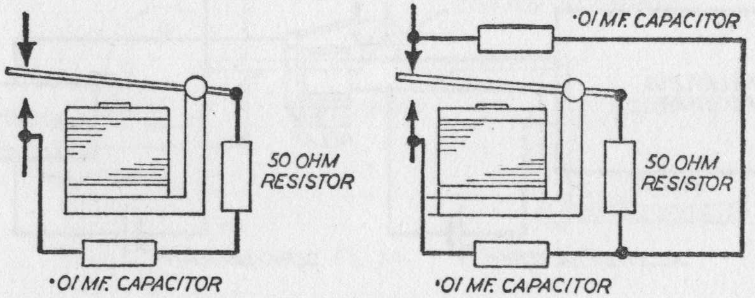


Fig. 7.4.

A single signal—e.g. a "quick blip" signal provided by the main actuator in addition to the main signalled control (rudder)—can be used to operate a whole variety of ancillary services in sequence. All that it is necessary to do is to take this signal to a rotary switcher which, on receipt of a signal pulse, steps round to its next position, and so on—

e.g. see Fig. 7.6a. Separate circuits can be extracted from each step position, as shown in Fig. 7.6b. There can be as many ancillary circuits connected up in this way as there are number of "step" positions on the switcher. The number can be further increased by double-banking the switcher, or even treble-banking.

Any particular service can be selected only by stepping the switcher through the required sequence to reach a particular position. Thus if "service 7" was called for, and the switcher was at "0" to start with, seven blips would have to be given to step the switcher round to complete "service 7" circuit. In doing so, of course, services 1 to 6 would be momentarily completed.

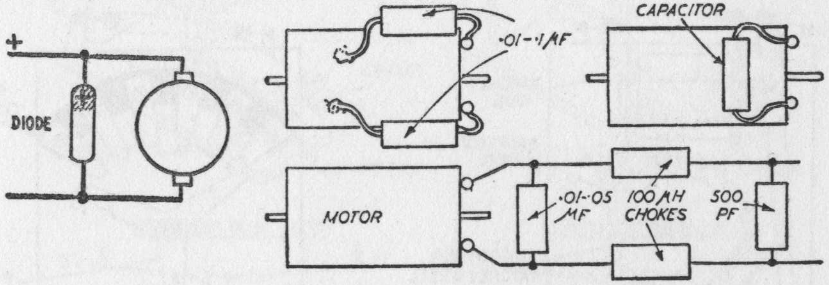


Fig. 7.5.

The next service required would have to be signalled *on* from the last position which does make a simple sequence switching system of this type rather complicated to master if signalled manually by individual pulses. A mechanical switch with similar positions can be used at the transmitter end to select a particular position and signal the appropriate number of "quick blips" to arrive at the same switcher position. The main difficulty here is that if a particular signal is missed the control switch and switcher will then be out of sequence. Thus a more satisfactory solution is to incorporate a means of cancelling the last signal and returning the switcher to zero. The next required sequence position can then be signalled directly by the appropriate number of pulses in the sequence. If this can be done mechanically by

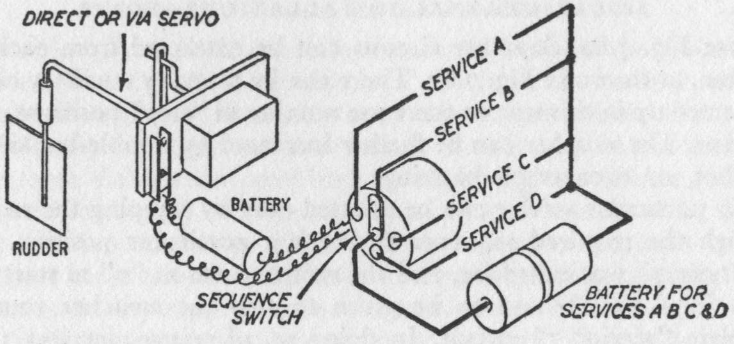


Fig. 7.6a.

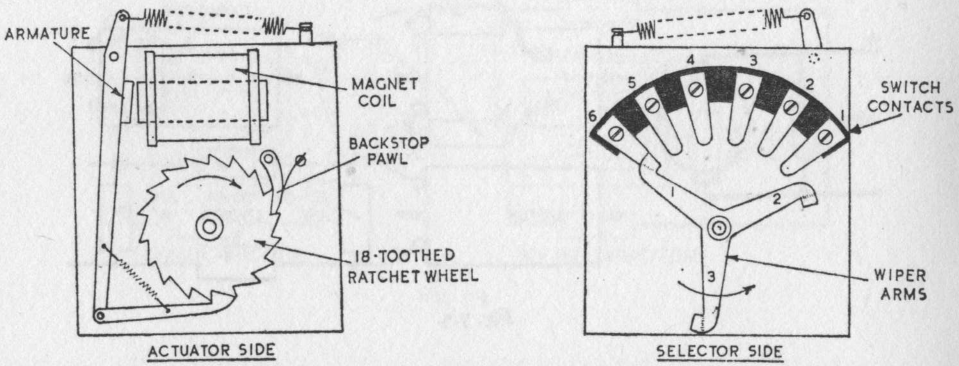


Fig. 7.6b.

dialling (or electronically) there is less chance of any of these pulses being a "false" signal, e.g. held a little too long and so unintentionally operating the main control with loss of sequence on the ancillary switcher circuit.

A switching circuit which can be worked by a simple escapement (e.g. signalled by a "third" position hold on the main actuator) is shown in Fig. 7.7. This gives, in effect, the switching capabilities of two relays. It can thus be used to control a "multi" servo off a single-channel signal.

The possible variations are too numerous to describe, particularly as

the solutions worked out are usually specific to the requirements of an individual model. The best source of information on such subjects is the monthly model radio control journals which regularly carry articles describing individual systems. With simple single-channel operation, however, the same basic recommendation applies that the main control (rudder) should not be included in a sequence of ancillary controls.

The ancillary circuits themselves can incorporate an actuator (or electric motor) where mechanical output is required (e.g. to operate a

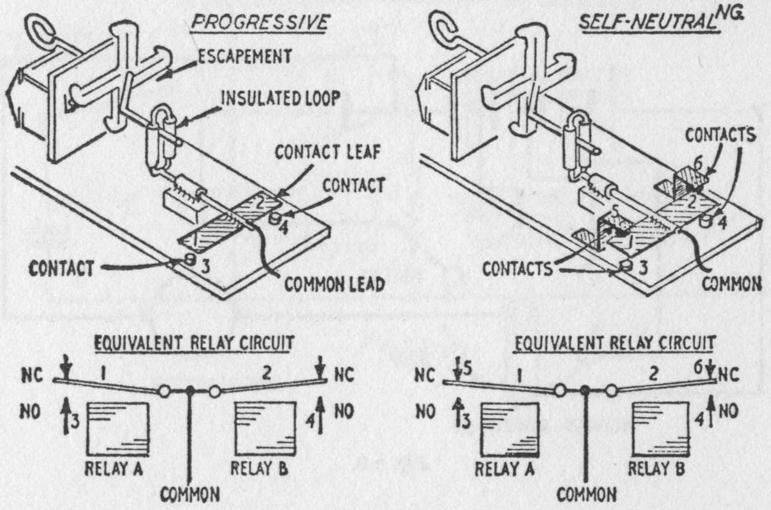


Fig. 7.7.

winch); or merely be simple electrical circuits (to switch on lights). They are separate circuits. The radio side merely provides the "on/off" switching. In the case of a single additional service this can be provided directly by the "third position" or "quick blip" contacts on the main actuator. For more controls this single "radio" switch has to be used to operate a separate switcher to provide additional "on/off" switching positions.

The rotary switcher which steps round one position at a time provides a popular electro-mechanical solution. A similar effect can also be produced by electronic circuits. The practical modeller will usually adopt "mechanical" solutions; the electrical enthusiast "electronic" switching, or a combination of both.

As an example, consider speed control for an electric motor. This can be provided by tapping the battery at various points to give different voltages and thus different motor speeds governed by the position of a stepping rotary switch; plus one additional position for "stop" and another position for "astern". These positions offer separate complete circuits in a definite sequence—Fig. 7.8.

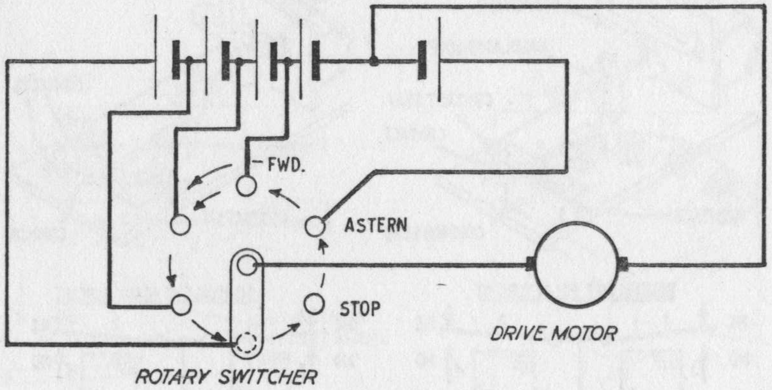


Fig. 7.8.

Instead of a rotary switch, relays can be used. A relay connected in a circuit such as that shown in Fig. 7.9 can be adjusted to change over its position every time it receives a signal pulse. A series of relays suitably connected will then act in sequence and can provide sequence switching just like the mechanical switcher. Such a circuit will also do more than the mechanical switcher in providing a positive sequence of operation with freedom from "skipping" and, with a little ingenuity, direct access to specific control positions, e.g. engine "stop". It is a little cumbersome, compared with a mechanical switcher, and introduces relay contacts into the circuit which may be affected by damp. A better solution still, therefore, would be to use transistor flip-flop circuits in place of relays to eliminate all contacts and make for even faster response; but the cost would be extremely high in comparison.

In the main, therefore, with simple single-channel controls mechanical or electro-mechanical solutions are adopted for ancillary service selection. It is also generally recommended that the number of services aimed at be kept to a minimum. More sophisticated switching systems belong more properly to multi-channel installations or the adaptation of simple proportional controls to boats.

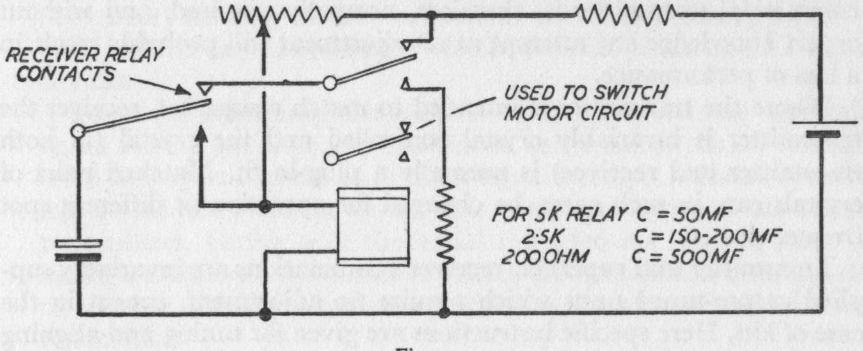


Fig. 7·9·

CHAPTER 8

SINGLE-CHANNEL OPERATION

All commercial transmitters are normally supplied pre-set and pre-tuned; and in the case of crystal-controlled transmitters the signal generated is at a specific "spot" frequency. No adjustment of a commercial transmitter is, therefore, normally required, and without expert knowledge any attempt at re-adjustment will probably result in a loss of performance.

Where the transmitter is intended to match a superhet. receiver the transmitter is invariably crystal controlled and the crystal (in both transmitter and receiver) is normally a plug-in fit. Matched pairs of crystals can, in such cases, be changed for operation at different spot frequencies.

Transmitter and superhet. receiver combinations are invariably supplied as pre-tuned units which require no adjustment, except in the case of kits. Here specific instructions are given for tuning and aligning the receiver circuit to match the transmitter and must be followed specifically. Further to assist home constructors, manufacturers of such kits (or their main agents, if such kits are imported into this country) usually run an alignment service which can be expected to give better working results where the home constructor has not got access to an oscilloscope.

Superregen. receivers, which form the main bulk of single-channel equipment, normally require tuning to a particular transmitter in order to achieve optimum results. Equipment purchased as transmitter–receiver combinations will normally include a receiver tuned to the transmitter as a working check, but final tuning should always be carried out after installation in a model. Modern sets have a single tuning control only, which considerably simplifies this operation. It is unnecessary to use instruments for tuning, unless relay adjustment is found necessary with a relay-type receiver. Then a milliammeter will be needed to insert in the receiver circuit to set up the relay adjustment for optimum "pull in" and "drop out" points. Again this should not

be necessary with new equipment for the relay will be pre-adjusted. Re-adjustment may be necessary after a crash, however.

For tuning adjustment the complete receiver installation should be wired up ready for working. With both the transmitter and receiver switched on, the transmitter should be keyed, when the receiver should respond. This is seen by the working of the actuator. In the case of a relay-type receiver the actuator circuit can be disconnected, when working can be judged by the clicking of the receiver relay. This is an incomplete check, however. Receiver working is always best judged by the correct working of the final output (i.e. the actuator) as this will then include any interreaction effects between actuator and receiver circuits.

To avoid swamping the receiver with an overstrong transmitter signal for the initial check, transmitter and receiver should be located a few feet apart and the transmitter signal strength reduced by retracting the aerial. Note, however, that with some types of all-transistor transmitters, keying with the aerial retracted *can result in circuit overloading and damage to the transistors*. Check the instructions first, therefore, to see that it is permitted to operate the transmitter with the aerial retracted.

Tuning adjustment is normally an iron dust core in the centre of a coil, the end of the core being accessible through a hole in the receiver case. This core end is either slotted or has a hexagonal indentation and can be tuned by inserting a tuning wand with an appropriate tip (i.e. a screwdriver tip or a hexagon tip). This wand must be of insulating material. A metal screwdriver cannot be used as its proximity will affect the tuned circuit characteristics.

With the transmitter signal held on the receiver will probably respond. If not, turn the tuning core one way or the other until the receiver circuit does operate. Now turn the tuning core in one direction until the receiver circuit suddenly switches off. That establishes one limit position. Now turn the tuning core back again when the receiver circuit will switch on again and, continue turning in the same direction until it switches off again. This will establish the other tuning limit. The optimum tuning position then lies mid-way between these two "limit" positions, so turn the tuning core back to this—Fig. 8.1.

Exactly the same procedure should now be repeated for a "range check". This time the transmitter aerial is fully extended and the receiver moved a considerable distance away. The distance depends on the application. Thus for aircraft the "range check" should be made with transmitter and receiver separated by at least 100 yards—and 200 yards is a better figure. For boats the range check should be at least the length of the pond on which the boat is to be operated.

With the receiver initially set to optimum tuning it should respond immediately to the transmitter signal. Turning the tuning coil first one way and then the other to establish the limit positions again, however, will show that the limits are less widely separated and the optimum or mid position will probably be different to that established by the initial check. This is the final setting, although if there is still a fairly wide range between the "limit" positions it will be advantageous to increase the range still further and repeat the tuning process for even finer tuning.

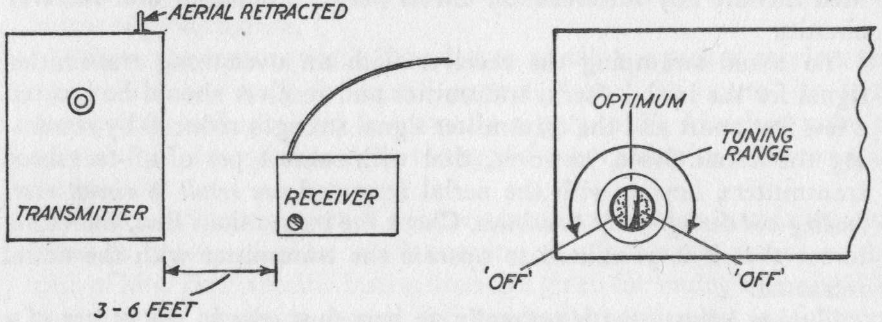


Fig. 8.1.

With boats, although a range check can be carried out over the ground for convenience, a final check should be made with the boat in the water and the full length of the pond away from the transmitter, adjusting for optimum tuning in the same way as before.

Range tuning demands the co-operation of another person and it is important to establish a visual signal code so that one operator knows what the other is doing. Thus the person adjusting the receiver can turn to face the transmitter operator when he wants a signal "on" and away when he wants the signal "off". Alternatively he can indicate signal "on" wanted by an arm raised; or "off" by the arm lowered, although this will leave him only one hand free for adjustment. The actual code used is not important, provided both people concerned agree on the signals to be used.

At extreme range some peculiar effects may be noticed, such as the receiver responding to the transmitter signal only when the aerial wire is broadside on to the transmitter; or perhaps the signal will be picked up only when the model is held overhead and not when standing on the ground. This is not significant if the range is 300–400 yards or more and in fact is quite normal at such distances. It can indicate lack of range with the particular transmitter–receiver combination if it occurs at much less than 300 yards.

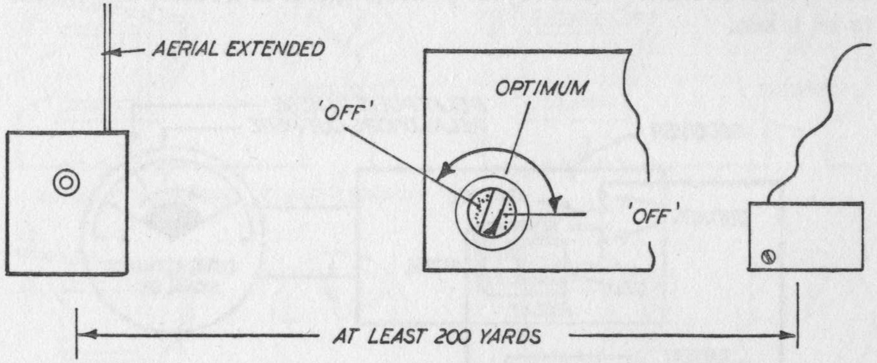


Fig. 8.2.

Modern receiver circuits are usually extremely stable so that once tuned they stay tuned. Thus it is unnecessary to repeat range checks at frequent intervals. A simple close-range check is sufficient, which is readily carried out as follows.

Having set up the receiver tuning at range, find the maximum range at which it will still respond with the transmitter aerial fully retracted. This may be a matter of ten or fifteen yards, or perhaps less. If this check is then repeated every time before use it will establish that the tuning is still correct. A marked reduction in the short-range distance would indicate that the receiver has gone off tune and needs rechecking through completely.

Before the model is ready to operate, however, it still needs a complete running check—that is, with everything switched on and the engine running (and in the case of a boat with the boat in the water), and the model held stationary. This will show up any possible interference through engine vibration. If controls do not operate positively on such a check then the cause of the trouble must be traced and cured. See the check chart (Table 11) for possible causes of troubles and action to be taken.

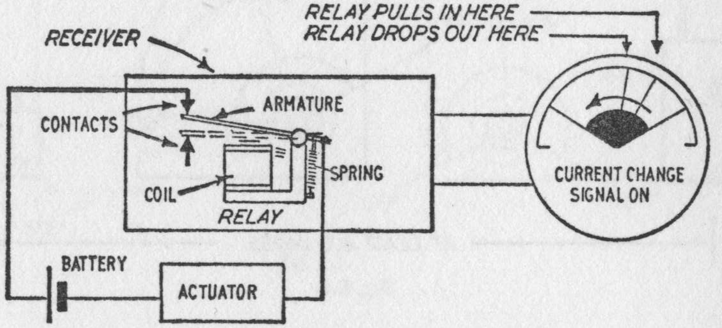


Fig. 8.3.

Relay-type receivers are particularly susceptible to vibration, and especially if the relay is of poor quality or is incorrectly adjusted. Vibration can also cause fastening screws on actuators to work loose and stressed soldered joints to fail (which is why "tight" wiring between terminal points should always be avoided).

Relay adjustment technique can be studied with reference to Figs. 8.3 and 8.4. Its action is to "pull in" at a certain current value flowing through the receiver circuit and "drop out" when the current falls below a certain value. All receivers operate on a current-change basis, with a maximum or "top" current flowing through the circuit when the receiver is responding to a transmitter signal, falling to a much lower "idling" current when the transmitter signal is switched off. The "pull-in" current for the relay is adjusted to be somewhat below the top current to allow a safety margin, for this current will tend to decrease with range and falling battery voltage. The relay will remain pulled in until the current has fallen for some amount below the "pull-in" current, the difference between the "pull-in" current and the current value at which the relay drops out being known as the differential.

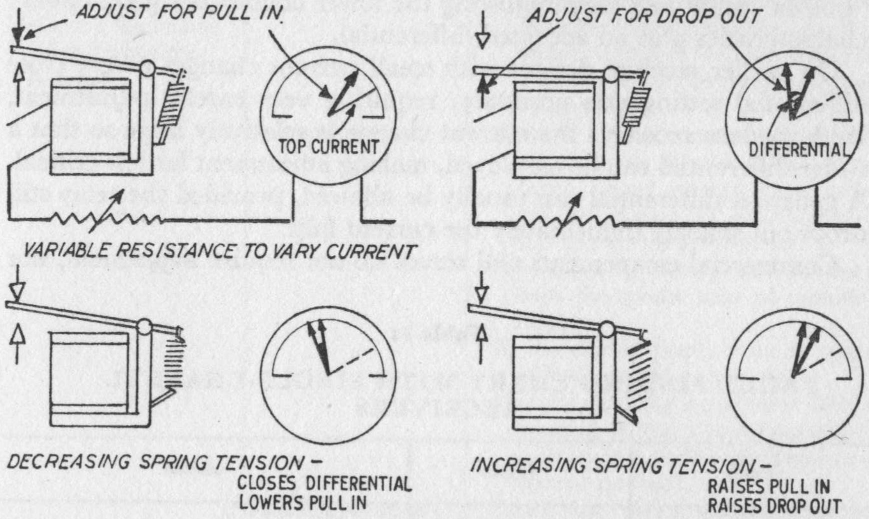


Fig. 8.4.

Basically, the position of the back contact of the relay governs the "pull-in" current. Screwing (or bending) this contact towards the armature lowers the "pull-in" current required and vice versa. Similarly, decrease in spring tension will decrease the "pull-in" current; and an increase in spring tension increase the "pull-in" current, although spring tension is not normally used as a method of adjustment unless it is badly out to start with, e.g. the tag locating the bottom of the spring may have been accidentally bent.

The position of the lower contact governs the drop-out current. The closer this allows the armature to approach the core of the coil the more the relay will tend to hold in, i.e. the greater the differential. If the lower contact position actually allows the armature to touch the coil core the armature may delay dropping out until a little time after the current has been switched off completely, thus some air gap is essential to get a differential at all. However, the closer the armature is to the coil core when pulled in the more strongly it is held, and thus the less affected by vibrations. Relay adjustment, therefore, is essentially a compromise—setting the back contact position to give the required "pull-in" point and then adjusting the lower contact for good "hold" characteristics plus an accepted differential.

On earlier receiver designs with small current changes a very close differential setting was necessary, requiring very careful adjustment. With modern receivers the current change is relatively large so that a wider differential can be employed, making adjustment far less critical. A generous differential can usually be allowed, provided the relay still drops out smartly immediately the current falls.

Commercial escapements and servos do not require adjustment, nor

Table 11

FAULT FINDING CHART WITH SINGLE-CHANNEL RECEIVERS

Fault	*Cause*	*Action*
Does not work when switched on (Connect a 0–10 milliammeter to one battery lead and see if a reading is obtained with set switched on.)	Connection fault	(i) Check actual wiring to see if it agrees with instructions. (ii) Check for broken wires or poorly soldered joints. (iii) Check battery connections (especially spring pressure in battery boxes). (iv) Check that switch is working properly and not defective due to dirt, etc. (v) Check that shorting plugs are in position (where used).
	Circuit fault (component)	Faulty component or broken connection.

Table 11—continued

Fault	*Cause*	*Action*
Does not respond to transmitter (Current should *fall* to a low value when transmitter is switched on; then *rise* to a high value when transmitter is keyed	Weak batteries	Check actual battery under load with suitable voltmeter—preferably after the battery has been on for 2–3 minutes. An absolute minimum load voltage for satisfactory operation with dry batteries is 0·8 times the nominal battery voltage. Replace batteries if approaching this minimum load voltage figure.
	Faulty tuning	Re-tune against transmitter (transmitter on) at short distance and at range. Do not attempt to tune near possible sources of interference—e.g. an iron shed, fence, etc. In the case of aircraft: tune at range with the model held at shoulder height. In the case of boats: tune at range with the model in the water. In both cases the transmitter should be used in the normal operating position (e.g. held in the hand in a normal manner).
	Relay adjustment faulty (Relay receivers)	Check that relay *is* working—e.g. by switching receiver on and off. If working, readjust to circuit specification or manufacturer's recommended "pull in" and "drop out". If not working, suspect mechanical fault in relay.
	Faulty actuator (Relayless receivers)	Actuator may not be matched to receiver output. Check working independently on separate battery. Check wiring-up connections.
	Transmitter fault	Transmitter batteries, may be weak or transmitter faulty, transmitter aerial not connected or extended, or poor connection.

Table 11—continued

Fault	*Cause*	*Action*
Relay or escapement "chatters" (Motor not running)	Faulty relay adjustment	Check relay adjustment. (Applies to relay receivers only.)
	Critical tuning	Check tuning at range.
	Faulty tuning	Re-tune as above.
	Transmitter fault	Check transmitter for correct operation, e.g. from another transmitter.
	Outside interference	
Relay or escapement "chatters" (Motor running)	Engine/propeller combination	Check propeller balance or change propeller.
	Receiver mounting	Improve shock-resistant mounting of receiver or mount in a different attitude.
	Faulty adjustment	Relay adjustment may be faulty or weak batteries giving poor "hold in".
	Electrical "noise"	Insulate or bond metallic linkages.
Lack of range	Faulty adjustments	Check relay operating points and differentials against recommendations. Specifically check top current at range (batteries may be weak).
	Critical tuning	Re-check tuning.
	Weak batteries	Check receiver and transmitter batteries under load.
	Inefficient aerial	Check that aerial length is correct; end of aerial wire is not being "earthed" (e.g. bare end touching hull in boats); aerial connection is not broken.
	Transmitter fault	Check transmitter operation independently.

Note: The most common causes of receiver faults are:
(i) Weak batteries.
(ii) Interference from actuator "noise".

is there any provision for adjustment. One therefore has to rely on the unit being suitable for use "as bought".

In certain cases the performance of escapements can be improved by careful adjustment. Thus with a "sticking" escapement the cause may be a small burr or roughness on the edge of the pawl or escapement arm when these surfaces will benefit by smoothing with an oilstone. Filing will almost certainly roughen the surfaces and give a worse rather than better performance. Escapement movements are invariably delicate and easily distorted or bent out of shape. This can cause "skipping" as well as binding; in which case a cure can be affected by very carefully bending parts which may be out of alignment.

An escapement which does not give a consistent performance on test is not worth installing in a model. It will only be a constant source of trouble.

Actual operating technique with the system in use is something which needs practice to master, when manipulation of the transmitter key becomes instinctive, particularly when using a compound actuator. Keyed signals have to be "timed" to match the rotational speed of the actuator, but this technique is mastered very quickly. It is then a matter of practice and familiarity to match control requirements to corresponding movements of the model. Responses have to be rapid in the case of aircraft controls, and over-controlling avoided (i.e. holding on a control position for too long). With boats the response of the model is so much slower that there is more time to think about control manipulation, although control of a high-speed boat powered by a diesel engine requires almost as rapid reactions on the part of the operator as aircraft. Response to control movement is obvious in the case of boats. With aircraft, although rudder is the main control, even rudder-only does permit a wide variety of other manoeuvres to be performed. These can be further expanded with a "third" control available. As a general guide, control possibilities are summarized under separate headings:

Level turns—The *same* rudder signal is blipped on and off at a rate which "rocks" the model into a banked turn without losing too much height. This is easiest to perform with a compound actuator allowing right rudder to be selected by "press and hold"; and left rudder to be selected by "press-release-press and hold".

Table 12

FAULT FINDING WITH SINGLE-CHANNEL ACTUATORS

Fault	*Cause*	*Action*
Control surface or actuator "chatters"	Excessive vibration and excessive slack in linkages	Change propeller or balance propeller to reduce vibration. Reduce "free" movement in linkages.
	Escapement motor too strong—causes escapement to "skip" under vibration.	Replace with smaller section motor or reduce number of turns supplied.
	Escapement motor wound wrong way	Immediately apparent as it occurs on winding the escapement motor.
	Escapement faulty	Pawl or detent not properly raked or set.
Control surface or actuator sticks "on"	Escapement motor too strong—locks escapement	Replace with smaller section motor or use less turns.
	Escapement motor unwound	Enough power for one movement but not return.
	Escapement fault	May be burr on pawl or detent. Check and adjust for proper action.
	Excessive friction	Check linkage for freedom of movement.
Control surface or actuator sticks "off"	Escapement motor unwound	Check that it is rewound the *correct* way.
	Escapement motor too weak.	May stick "on" or "off."
	Weak actuator batteries	Insufficient to energize coil. Replace.
	Excessive friction	Too much "binding" for escapement motor to move linkage—so free up.
	Excessive aerodynamic load	Use aerodynamic balance to cure. *Note:* Excessive aerodynamic load at high speeds may equally well lock a control position "on" by distorting the linkage and causing binding.

Table 12—continued

Fault	*Cause*	*Action*
Controls do not operate	Weak actuator batteries	Check voltage under load.
	Excessive friction	Hinges stiff or linkage binding.
	Actuator circuit fault	Isolate actuator circuit and check operation independently. (i) Possible wiring faults or disconnections. (ii) "Dry" solder joints. (iii) Actuator coil fault.
	Dirty contacts	Check and clean as necessary. Re-adjust contact pressure.
	Damaged contacts	Contacts may be pitted, burnt or even welded by using excessive actuator voltages (this also includes relay contacts).
	Mechanical failure	Check for binding linkages, broken or seized hinges, etc.
Controls inter-act	Electrical interference	Suppression or bonding may be needed, if not already used.
	Weak batteries	Additional load to second actuator too much for battery capacity.

Diving turns—The same rudder position is blipped on at more frequent intervals.

Spiral dive—Either rudder position is held on. Recovery is by releasing the rudder control. Allow plenty of height for this manoeuvre, and enough height for the model to recover to normal flight when the rudder is centralized.

Climbing turn—Blip on the same rudder position at regular but well-spaced intervals.

Loop—Put model into a spiral dive from a good altitude and after two

Table 13

FAULT FINDING CHART FOR SINGLE-CHANNEL TRANSMITTERS

Fault	*Cause*	*Action*
Apparently no signal (No reading on field strength meter)	Faulty adjustments	Check against manufacturer's specifications.
	Circuit disconnection	Check for broken or disconnected wiring, fault in keying lead or switch.
	Circuit fault	(i) valve may be displaced from its holder, or broken. (ii) component failure (more difficult to trace without specialized knowledge—return transmitter for check and service if necessary).
Weak signal or lack of range (Low reading on field strength meter and short range)	Faulty adjustments	Receiver may not be correctly tuned to transmitter.
	Aerial fault	(i) Check that aerial is proper length (also that the loading coil is incorporated, where specified). (ii) Check that aerial is properly mounted (e.g. good connection at base). (iii) Check that joints are not oily or dirty on telescopic aerial. (iv) Check that aerial is not earthing through faulty socket or moisture on socket.
	Weak batteries	Check batteries under load. Load-voltages should never be less than 0·8 times nominal battery voltage.
	Unfavourable operating conditions	(i) Transmitter on damp ground with variable "ground coupling" effect. (ii) Output affected by presence of overhead wires, etc.

Note: By far the most common fault is weak batteries.

or more complete turns, release control to allow the model to recover into straight flight heading into wind. If it has picked up sufficient speed it should complete a loop unless the trim is under-elevated.

With "trip elevator" or "up elevator" available as a "third" control, build up speed in a spiral dive, allow model to straighten up, then hold on elevator. With sufficient speed this can also produce consecutive loops.

Roll—Put model into a spiral dive from a good height, allow to recover in a crosswind direction and go into a zoom. At the top point of the zoom, hold on rudder. If this is not effective, try first blipping on one rudder position and then follow immediately by holding on the opposite rudder.

Stall turns—Put model into a spiral dive to build up speed, then allow to recover. At top of resulting zoom, blip on rudder.

Losing height—Blip on opposite rudder alternately to make the model perform S turns continuously but still following the same general direction of flight into wind. This needs considerable practice as it is easy to "lose" control and allow the model to complete a full 180-degree turn.

There are many other possibilities. The performance of a single-channel aircraft will also depend both on its design and trim. Some model designs are more manoeuvrable than others and have better response characteristics (see Chapter 2). Also if a model has a more or less normal free-flight trim it will be prone to zoom on recovery from turns and will more easily loop following a spiral dive. On the other hand, it will lack penetration and the ability to lose height under control compared with a model which is deliberately under-elevated in trim and faster flying.

CHAPTER 9

SINGLE-CHANNEL "PROPORTIONAL" CONTROL

CONVENTIONAL single-channel systems provide a "bang-bang" movement of the main (rudder) control which, if held on, provide a quite drastic response in the case of aircraft. There are no intermediate control positions and the effect of a lesser amount of control can be reproduced only by momentary use of the controls, produced by "blipping" the transmitter signal on. A similar principle can be extended to produce a more truly "proportional" control movement, or rather intermediate control position effect, by applying the transmitter signal in the form of bursts of "on/off" signals or pulses and modifying the actuator design to respond in a "proportional" manner.

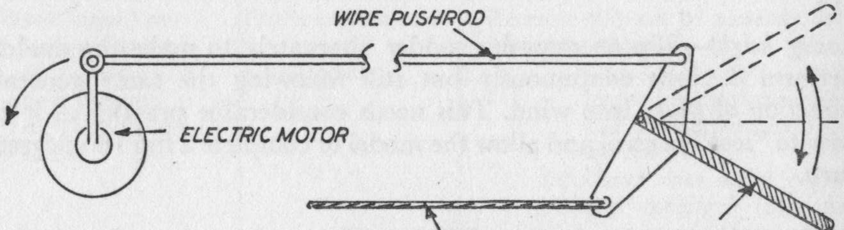


Fig. 9.1.

An elementary system of this type is shown in Fig. 9.1. The actuator in this case comprises a small electric motor linked to the rudder control so that it moves the rudder to the left when the motor is driving. Rudder movement is limited by a stop and so the motor needs to incorporate a slipping clutch in its output drive to continue running (with the clutch slipping) in the full-left rudder position. Without a clutch the motor would be stalled at the full-left rudder position and under this condition would draw a very high current from its battery. The rudder is biased to move in the opposite direction by a spring.

Thus with no current supplied to the actuator (motor) the control position will be right rudder. With a continuous signal held and completing the motor circuit, the motor will drive the control to left rudder position. If instead of a continuous signal, however, a pulsed signal is applied the motor will be switched on and off at the rate of pulsing. By varying the pulses the rudder can be made to assume any intermediate position from left to right in direct relationship to the "on" and "off" times of the motor circuit switching governed by the pulses received by the receiver.

Pulsing can be done manually—similar to "blipping" the transmitter key with conventional signalling—or produced by a mechanical or electronic unit connected to the transmitter circuit. "Proportional" positioning of the rudder can be achieved by varying the pulsing rate; or rather more accurately by varying the pulse width or ratio of signal "on" to signal "off" (or mark : space ratio, as it is usually called).

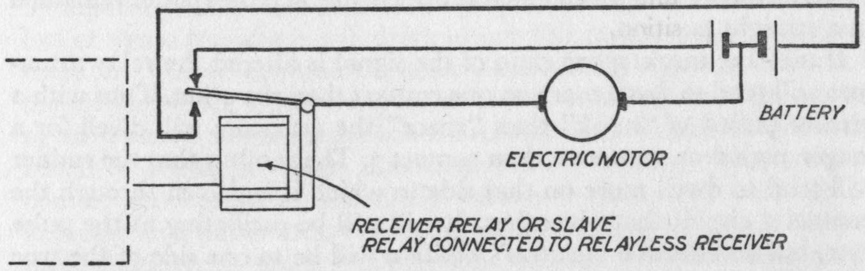


Fig. 9.2.

It will be appreciated that unlike conventional single-channel this system works on a continuous, if interrupted (pulsed), signal being used to produce a rudder position other than full right (no signal at all) or full left (continuous unpulsed signal). Also it has no definite neutral position and no self-centring action. It is thus unsuitable for aircraft, but it can be used for boats.

A better arrangement is to use a relay receiver with a relay suitable for following a pulsed signal and employ all three relay contacts for switching a motor with opposite polarity battery in a circuit like that shown in Fig. 9.2. A crank on the motor spindle is used to move the rudder but the movement is centred by a spring so that with no current flowing through the motor the rudder is pulled to the neutral (centre) position.

The pulsed signal in this case must have variable mark: space ratio. A "mark" signal corresponds to the relay being pulled in, closing contacts 1 and 2 and completing the motor circuit for the motor to drive in one direction. A "space" signal corresponds to the relay dropping out, completing the motor circuit through contacts 1 and 3 so that it will drive in the opposite direction. Thus with equal periods of "mark" and "space" (50:50 mark:space ratio) the relay armature will move backwards and forwards at the *rate* of pulsing, causing the motor to drive alternately in one direction and then the other, moving the rudder an equal amount from side to side. If the pulse rate is high enough—e.g. 7 to 10 times a second—this will have virtually no effect on performance and the model will behave just as if the rudder remained in a straight position.

If now the mark:space ratio of the signal is altered the relay armature will tend to dwell more on one contact than the other. Thus with a greater period of "mark" than "space" the armature will dwell for a longer period on contact 2 than contact 3. The result is that the rudder will tend to dwell more on that side to which it is driven through the contact 2 circuit than the other. It will still be oscillating at the pulse rate, but its effective "neutral" position will be to one side of the true neutral or straight position. Also the amount the effective neutral position is displaced to one side will be proportional to the mark:space ratio producing it. The same applies for proportional movement in the opposite direction, when there is a greater period of "space" than "mark".

Basically, therefore, the effective position of the rudder as a control surface can be varied infinitely from one side to the other in direct proportion to movement of a control at the transmitter end varying the mark : space ratio of the signal from 100 : 0 to 0 : 100 mark : space and with a 50:50 mark:space signal giving a neutral position. All that the system needs is a pulser to connect to the transmitter circuit; and a suitable actuator connected to a relay-type receiver. The actuator can be a slightly modified electric motor, as described; or a special type of proportional actuator which is normally based on two coils.

In practice the system can be extended to further services. Thus the full range of rudder movement required would be obtained over a mark:space ratio of, say 80:20 to 20:80. The two extreme positions—100:0 or continuous signal (all "mark"), and 0:100 or no signal (all "space")—could then be used to close separate electrical contacts for tripping secondary actuator circuits in the same way that a conventional compound actuator may have additional switching facilities. In this case the additional switching positions are selected by momentarily signalling either all "mark" or all "space", with the advantage that this can be done with separate press-buttons; or alternatively by a special circuit designed to detect a signal which is all "space" (i.e. a pulse omission detector).

The system still has distinct limitations, particularly for aircraft control. It still does not have a positive neutral, for this is achieved only by adjusting the pulser control for 50:50 mark:space ratio. Also with loss of signal the motor will drive to one full rudder position and stay there in a stalled condition. Further, the control response will not be *truly* proportional, for the actual position will be affected by "blow back" or air pressure acting on the control surface when displaced. Nevertheless it is a system which is attractive for providing "proportional" control movement at absolutely minimum cost, and both special actuators and pulser units are readily available. The latter will adapt to most commercial single channel tone transmitters with very simple connections.

With a suitable design of aircraft (often a low-wing layout), simple proportional control is a perfectly practical system to operate, although demanding more skill to fly than "bang-bang" single-channel. The pulse-rate adopted is usually high enough so that the oscillating movement of the rudder does not produce any marked effect on flight as would be observed with a low pulse rate. It is also adaptable to boat (rudder) control.

A somewhat improved performance may be expected by using a simple transistor switching circuit following the relay contacts, such as shown in Fig. 9.3. The choice of transistors does, however, limit the current which can be passed in the motor circuit without overloading the circuit, consequently it is best suited to motors which will perform satisfactorily on a low voltage supply and draw low operating currents, or magnetic actuators. The latter have a far lower mechanical output and are rather more suited for use on gliders than power models.

Simple proportional systems are particularly prone to be affected by interference, such as that generated by "noise" of rubbing metal parts and, in particular, interference from the motor. Bonding and suppression may therefore be essential requirements. Interference will also occur if the aerial wire is taken too close to other wires carrying varying currents. Thus the receiver aerial should be led directly away from other wiring and kept as far away as possible from the actuator.

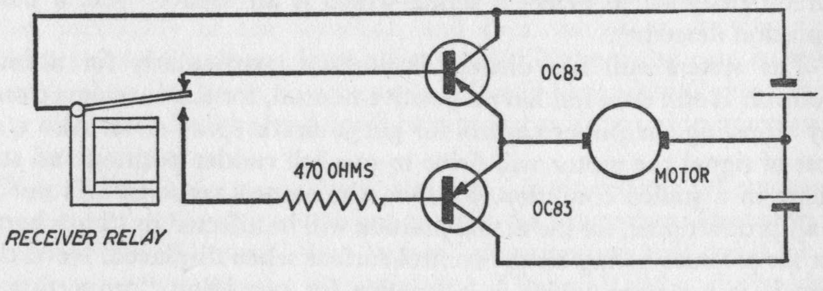


Fig. 9·3·

A further development which has evolved specifically as an aircraft control system is known as "Galloping Ghost". This works on a similar principle but involves the variation of both pulse rate and pulse mark: space ratio via a pulser unit at the transmitter end; and a special form of motorized actuator at the receiver end with mechanical output connected to drive both the rudder and elevators—Fig. 9.4.

"Proportional" rudder control is obtained in a similar manner to that described above. Variations in mark:space ratio of the signal causes the motor to oscillate with an effective mean position determined by the actual mark:space ratio, with 50:50 mark:space providing a central position—Fig. 9.5. At the same time the linkage will be oscillating at the pulse rate of the signal.

This linkage is also driving the elevator yoke as well as the rudder yoke. The elevator is thus oscillating as well as the rudder. With a moderate pulse rate—usually of the order of 6 pulses per second—the

effective mean position for elevator oscillation will correspond to "neutral" elevator position. If the pulse rate is decreased—say to about 4 pulses per second—the amplitude of oscillation of the linkage will reach a maximum and the corresponding mean position assumed by the elevator yoke will be raised to the equivalent of "up" elevator position. Similarly, if the pulse rate is increased, say to 8 pulses per second, the amplitude of oscillation of the linkage will be reduced to a minimum and the corresponding mean position of the elevator yoke will be equivalent to "down" elevator position—Fig. 9.6.

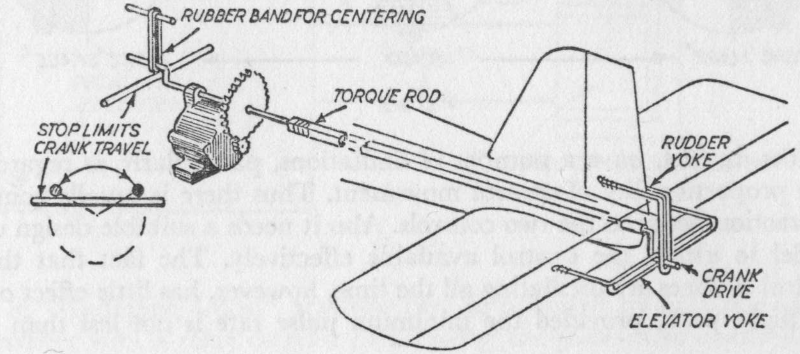


Fig. 9·4·

Thus, variation in mark:space ratio provides "proportional" rudder control over the full range of rudder movement from right to left; and variation in pulse rate provided "proportional" elevator control between full "up" and full "down" elevator. Proportional rudder and elevator control positions can thus be selected independently, or simultaneously, as required, merely by manipulating the controls at the transmitter end governing mark:space ratio and pulse rate, respectively. On most pulsers the two control circuits are actuated by a single stick, movement of the stick from side to side controlling the mark:space ratio and giving a proportional rudder position; and movement of the stick fore and aft controlling pulse rate and elevator position. The pulser circuit itself can be mechanical, or, preferably, all electronic, when it becomes just another "black box" to attach to the transmitter.

Commercial transmitters are also produced with the pulse units built in.

"Galloping Ghost" is by no means a complete and foolproof system.

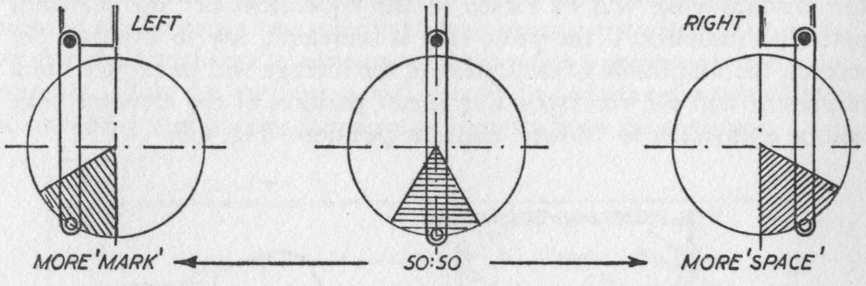


Fig. 9.5.

It does, in fact, have a number of limitations, particularly as regards true proportionality of control movement. Thus there is usually some interaction between the two controls. Also it needs a suitable design of model to utilize the control available effectively. The fact that the control surfaces are oscillating all the time, however, has little effect on the flight path, provided the minimum pulse rate is not less than 4 pulses per second. With lower pulse rates the model will show a marked tendency to follow the oscillation of the control surfaces and be more difficult to control.

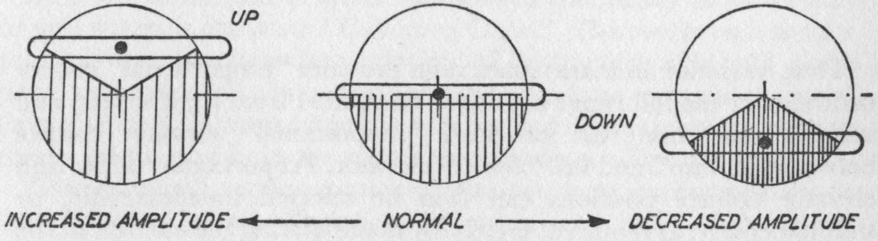


Fig. 9.6.

Successful operation, too, depends on the use of a suitable actuator. All the original systems employed modified electric motors for "Galloping Ghost" actuators, but special commercial actuators for this type of single-channel control system are now available. Although their cost is high they can normally be relied upon to provide a much better and more consistent performance than home-built units. They also normally incorporate an additional switching position for operating a further control via a conventional secondary actuator—e.g. engine speed changeover—or even a progressive throttle action derived directly from the main actuator.

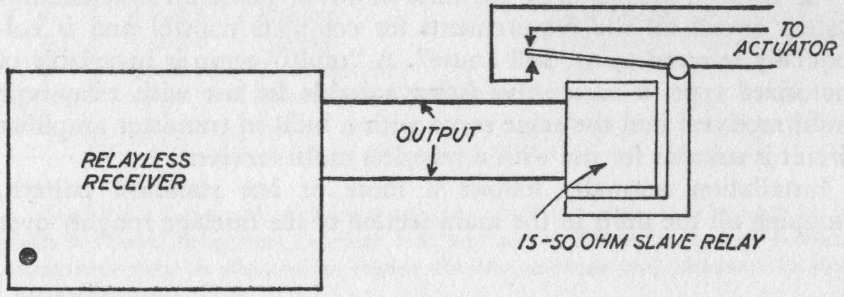


Fig. 9.7.

A "Galloping Ghost" actuator can be operated by any relay-type receiver with a relay capable of following the pulse-rates involved. In the case of a relayless receiver the addition of a slave relay is necessary (see also Chapter 6), to which the actuator can be connected—see Fig. 9.7. It is important that this relay should be suppressed if necessary (see Chapter 8) and also that the actuator itself, which is invariably motorized, does not interfere with the receiver operation.

As an alternative to a slave relay a special transistorized switching circuit may be used with relayless receivers. Also some relayless receivers are produced in "double-ended" form specifically for use with single-channel proportional actuators. The output in such cases may or may not be suitable for driving a motorized actuator (e.g. for "Galloping Ghost"), but would normally be suitable for direct connection to magnetic actuators of matched output load resistance for simple pulsed-proportional rudder control. The "matching" capabilities of such equipment should therefore be checked when purchasing such equipment.

CHAPTER 10

MULTI-CHANNEL INSTALLATIONS — AIRCRAFT

MULTI-CHANNEL installations require one "multi" servo for each control, allocated, on the lines shown in Table 14. A 10-channel system covers all the requirements for complete control and is colloquially referred to as "full house". A "multi" servo is invariably of motorized type, a basic servo being suitable for use with relay-type multi receivers and the same servo with a built-in transistor amplifier circuit is suitable for use with a relayless multi receiver.

Installation normally follows a more or less standard pattern, grouping all the units in the main section of the fuselage roughly over the same length as occupied by the wing chord—Fig. 10.1. The receiver is mounted in front of this compartment, adjacent to the front bulkhead; the batteries farther forward, and preferably in front of the bulkhead.

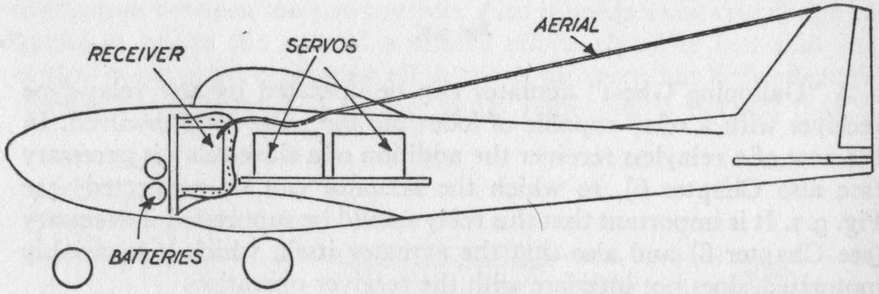


Fig. 10.1.

The receiver is again loosely mounted. It is best located in an oversize box or compartment and wrapped around with vibration insulation material. It should never be rigidly mounted to the fuselage. The best attitude for the receiver is in a vertical position so that the reed comb is vertical and aligned fore and aft. This will place the reeds in a plane where they are least likely to be affected by engine vibration. This would automatically align the relays in the same manner on a relay-type receiver. Where relays are mounted separately, then vertical mounting is the least likely to produce vibration troubles. In this case, too, the relays should be enclosed within a suitable casing so that they can be "loosely" restrained with a foam-rubber wrapping, like the receiver.

Table 14

ALLOCATION OF MULTI-CHANNEL CONTROLS

No. of Channels	*Channels*	*Control*	*Type of Servo*
2	1 and 2	Rudder	"Bang-bang", self-neutralizing
4	3 and 4	Engine throttle	Progressive (trim)
6	5 and 6	Elevator	"Bang-bang", self-neutralizing
8	7 and 8	Ailerons	"Bang-bang", self-neutralizing
10	9 and 10	Elevator trim	Progressive (trim)
12	11 and 12	Aileron trim* or ailerons	Progressive "Bang-bang", self-neutralizing

* Or rudder trim.

Note: With 6-channel equipment services would normally be allocated as 1–6; with 8-channel equipment, services 1–8; and so on. For pylon racing, 6-channel equipment may be allocated to engine throttle, ailerons and elevators (omitting rudder control).

Servos are normally mounted close together in a group, the standard method being to mount each servo on a plywood tray which is subsequently cemented to the fuselage. Insulation against vibration is provided by rubber grommets, as shown in Fig. 10.2. It is also a good plan to bind over fastening screws on the servo case with cellulose tape to ensure that these will not vibrate loose.

The servos represent the main weight of the radio equipment and so balance can be adjusted by sliding the servo tray backwards and forwards and the correct position for fixing established. The set of wires from each individual servo are best terminated on a multi-pin plug to connect with a matching socket. This enables the wiring to be simplified to some extent as power leads to the servos are common. Sockets for plugging in the servos can be mounted on the servo board, or merely left "floating" in the fuselage. Special mounting boards are produced to match specific makes of servos which can greatly reduce wiring-up problems. Sockets are incorporated on the board with common connections already established by printed circuit conductors. These special mounting boards are made in glass-fibre laminate which is stronger than Paxolin. They are heavier than a ply tray but make for a neater integral-wired assembly.

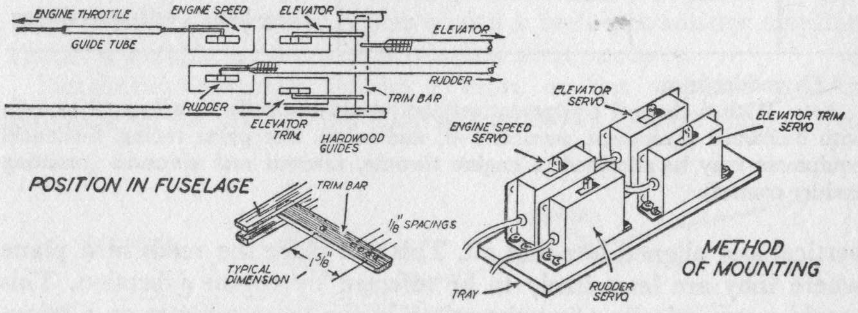


Fig. 10.2.

An alternative method sometimes used is to mount the servos on the side of the fuselage. If bolted in position the mounting surface should be thin ply rather than balsa, and grommets should again be used for vibration absorption. Instead of bolting in place adhesive bonding can be used. In this case the flat side of the servo is glued to a piece of fairly thick neoprene sponge sheet cut to a similar shape, and the other face of the rubber mount glued to the side of the fuselage. Contact adhesive is used for gluing. This provides a resilient mount and so a fairly dense rubber sponge is necessary to absorb the reaction to the output force of the servo in order to prevent the servo itself moving in the opposite direction every time it applies an output force. It is, however, a very satisfactory method of installing lightweight servos of suitable shape in a small model—Fig. 10.3.

In a normal "full house" complement the rudder, elevator, elevator trim and engine-throttle servos are installed in the fuselage, normally grouped in pairs and close together. The actual grouping depends on the method employed for linking the elevator and elevator trim servos. Thus the elevator and elevator trim servos may be placed side by side (Fig. 10.2), or one behind the other (Fig. 10.4), depending on the type of trim bar linkage used.

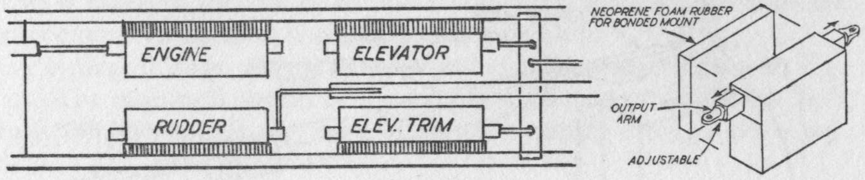


Fig. 10.3.

The output from a multi-servo is a push-pull movement. This is connected directly to the rudder or elevator via a push rod, which is normally made from hard square-section balsa with wire end fittings. These fittings are normally of a type which are readily attachable both from the servo output and the control horn, held in position by a thin wire keeper—Fig. 10.5. As a precaution, it is to be recommended that the keeper wire be bound in place with light wire (e.g. fuse wire) when finally assembled.

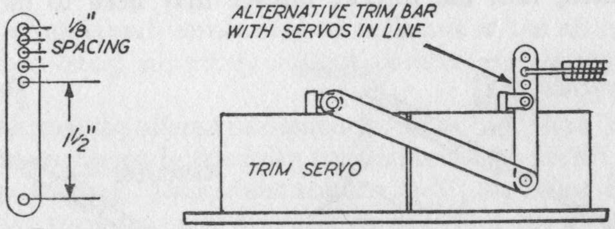


Fig. 10.4.

Proprietary linkage is also available with similar or clevis-type end fittings. Such fittings are usually screwed on to a rod and are thus adjustable for length. This is a particularly useful feature and an adjustable end fitting of similar type can be incorporated with advantage on home-made push-pull linkage.

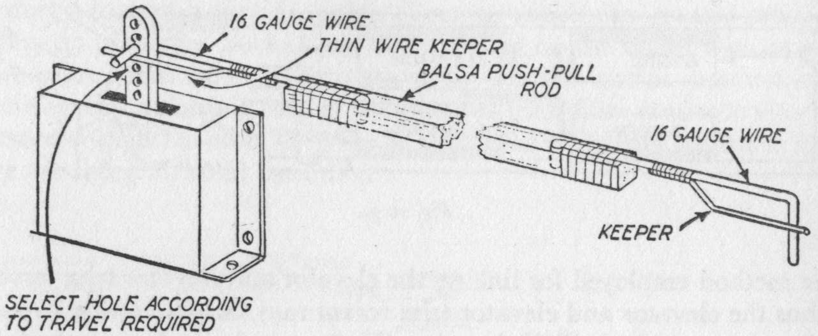


Fig. 10.5.

The throttle linkage must be rather different. Sometimes a Bowden cable is used running in a metal tube; otherwise it can be rigid wire running in a guide tube. The actual push-pull movement required at the throttle end may, however, be variable with adjustment of the throttle itself, thus the throttle linkage may need to incorporate a certain amount of flexibility. This can be done by incorporating an expanding-link section or a single-turn coil, as shown in Fig. 10.6. With Bowden cable control sufficient flexibility is usually given by the freedom of the cable to "bow" after emerging from the front end of its guide tube.

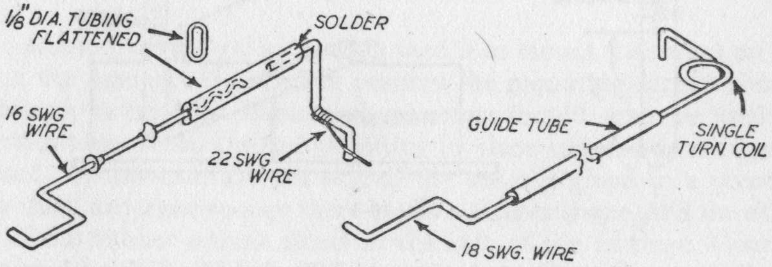


Fig. 10.6.

The complete aileron control system is mounted within the wing itself, which is usually detachable from the rest of the model. The aileron servo is fitted in the centre section of the wing and plugged into the main circuit via its own plug-and-socket assembly.

A typical linkage system for conventional ailerons is shown in Fig. 10.7. The push-pull output of the servo is used to operate a small bellcrank which controls the main pushrods running through the wing.

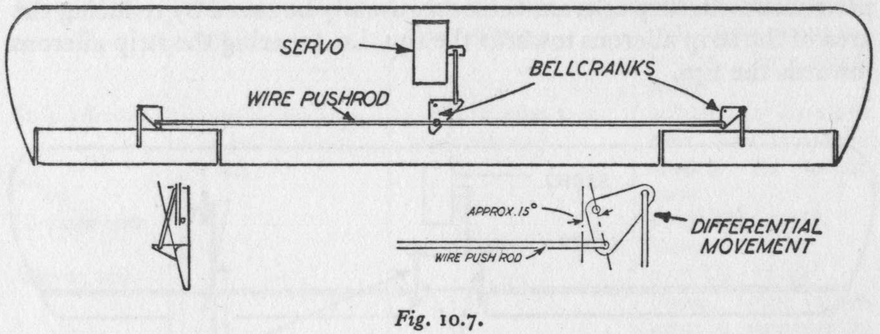


Fig. 10.7.

These main pushrods each terminate in a bellcrank at the aileron end, the aileron then being moved by a short pushrod connecting to the aileron horn.

It is desirable that the aileron movement be more "up" than "down". This is because an aileron in the down position increases the lift on that wing and also the drag. Thus whilst tending to lift that wing and roll the model into a turn, the extra drag also tends to hold the model back from turning. The result is that the model may yaw in the opposite direction rather than make a smooth turn. This effect can be eliminated by giving the ailerons differential movement—e.g. 25 to 35 degrees up and 15 to 20 degrees down. To obtain a differential movement it is only necessary to offset the aileron bellcrank, as shown in Fig. 10.7. An offset of about 15 degrees will give a suitable differential movement for most models.

Modern aerobatic designs favour the use of strip ailerons rather than inset ailerons. These are simply narrow strips hinged directly to the trailing edge of each wing. The operating linkage in this case can be contained within the wing centre section, such as shown in Fig. 10.8. An alternative and simpler solution sometimes used is to operate the strip ailerons directly by push-pull action via Bowden cables running in metal tubes. Conventional linkage is usually preferred, however, particularly as this lends itself more readily to adjustment of individual aileron settings. Note that with strip ailerons no differential movement is used, nor is it necessary. Actual aileron movement required is lower than with conventional ailerons. If adverse yawing effects are experienced with strip ailerons these can usually be cured by reducing the area of the strip ailerons towards the tips, i.e. tapering the strip ailerons towards the tips.

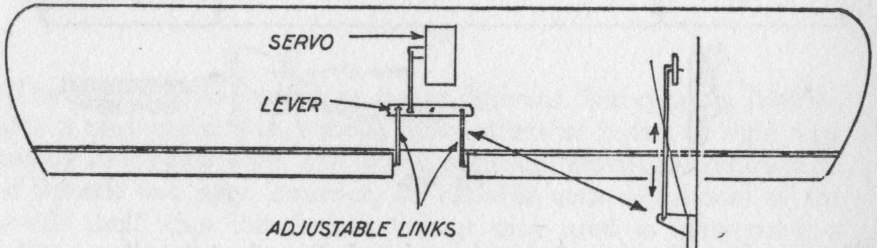


Fig. 10.8.

Actual movements required from the control surfaces will depend to some extent on the design of the model, its weight, power and trim. The values given in Table 15 are, however, typical. The amount of movement obtained is normally readily adjustable, for control horns normally have a number of hole positions for connecting the pushrod end. Moving the rod to a hole nearer the hinge line will increase the control movement, and vice versa. The main thing is not to have too much movement on elevator and particularly elevator trim, as this will only lead to over-control.

Table 15

AIRCRAFT CONTROL REQUIREMENTS

Control	*Type*	*Size*	*Movement range*
Rudder	Movable surfaces	2–3% of wing area	30° Right; 30° Left S/N
Elevators	Movable surfaces	4–5% of wing area	10° Up; 10° Down S/N
Ailerons	Movable surfaces (inset)	5–6% of wing area (each aileron)	30° Up; 20° Down for rolls. Less movement needed for steady turns
Strip ailerons	Movable surfaces Hinged to wing (T.E.)	4–5% of wing area (each aileron)	20° Up; 20° Down for rolls. Less movement needed for steady turns
Elevator trim	—	—	2–2½° Up; 2–2½° Down
Aileron trim	—	—	3–5° Up; 1½–2½° Down. Great movement is necessary for steady turns
Rudder trim	—	—	1–2° Right; 1–2° Left
Flaps	Movable surfaces	10–15% of wing area	30–45° Down (maximum)

The amount of aileron movement, on the other hand, may have to be adjusted according to requirements. Thus a moderate aileron movement may produce smooth turns but not enough aileron power to complete rolls. Enough aileron movement to give snap rolls, on the other hand, may produce too strong a force for ordinary turns. There is a very good case, therefore, for having two aileron control ranges on a fully aerobatic model, i.e. one servo which is used for producing moderate movements for turns; and another servo which produces large aileron movements for snap rolls. This is similar to the use of elevator and elevator trim, and the interlinkage could be on the same lines. Thus the aileron "trim" servo produces enough movement for turns; and the normal aileron servo full movement, each being switched by a separate key. The first servo could be used as a trim control, i.e.

using a progressive servo, but the system would be easier to fly if it operated on a "bang-bang" movement with self-centring.

There are numerous other variations possible, and necessary additional movements can often be initiated by "limit switching". Thus certain otherwise highly aerobatic designs are reluctant to spin, mainly because the amount of up elevator movement required for smooth flying control is insufficient to allow the model to be stalled into a true spin. An addition to the switcher board of the elevator servo can extend the output movement under certain conditions by inter-linked switching, e.g. when the throttle servo is in a closed position. Thus selection of these two control positions simultaneously gives the extra movement required on the elevator servo. Under all other conditions the elevator control movement will be normal. Inter-linked switching can also be extended to other services, such as cutting out rudder with coupled-aileron-rudder systems, as described in Chapter 2; or to extend the number of services covered by a limited number of channels. This would normally be limited to one additional service for practical operation and some possibilities are summarized in Table 16.

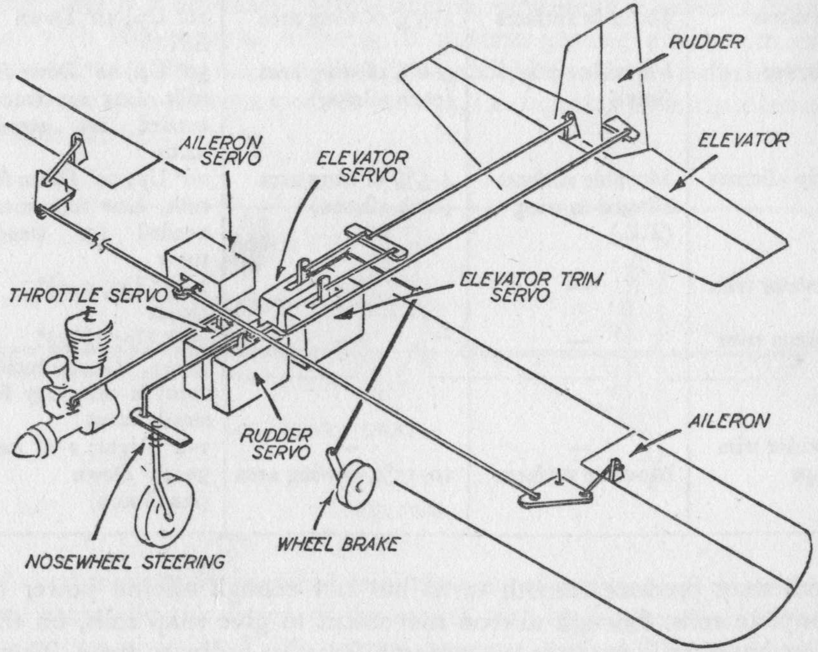


Fig. 10.9.

Table 16

TYPICAL COUPLED CONTROLS

(Functional only)

Control	*Coupling*	*Remarks*
Ailerons	Servo connected in parallel with rudder servo	Uncoupling of rudder can be provided, e.g. by throttle movement
Ground steering	Mechanically linked to rudder servo	Incorporate spring(s) in linkage to absorb shocks and lessen impact loads on rudder servo
Wheel brakes	Mechanically linked to rudder servo	Brakes operated by full "up" elevator position
Retractable undercarriage	Switched by a suitable limit position on a main servo	Operated by its own sequence-type actuator
Flaps	Switched by a suitable limit position on a main servo	—

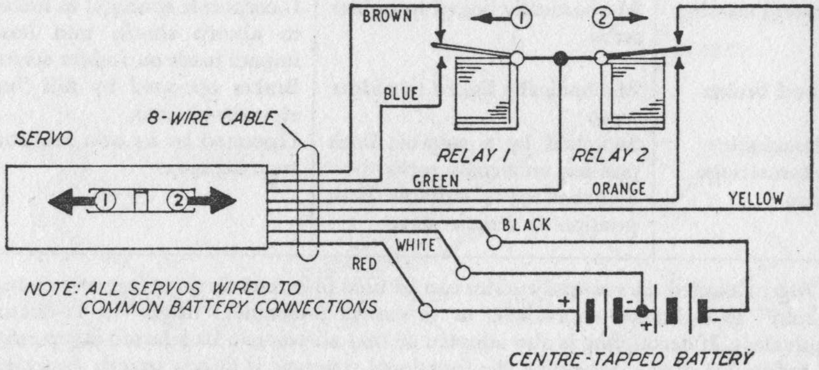
Note: Coupled aileron-and-rudder can be used to extend the coverage of 6-channel "multi" to 8-channel equivalent; or to extend 8-channel "multi" to 11-channel equivalent. If decoupling is also adopted so that aileron can be selected independent of rudder for most manoeuvres the functional coverage is almost exactly equivalent in practice. If decoupling is not used, than a coupled-aileron-rudder system will always have performance limitations.

A number of secondary controls may be mechanically linked. Thus with a conventional 10-channel installation the rudder servo would also operate nosewheel steering (or tailwheel steering directly linked to the rudder movement) and the elevator servo could also operate wheel brakes—Fig. 10.9. In the latter case wheel brakes are pulled on by full "up" elevator movement, the connecting link needing only to be a length of nylon line running to a simple brake mechanism.

Alternatively, commercial wheels are available fitted with hub brakes which can be worked by a similar pull action.

The electrical side involves a fair amount of wiring and thus careful attention to detail. Wiring schemes are essentially similar for all reed-type receivers, but will be dependent on whether the receiver is of the relay or relayless type.

Conventional multi-servos for use with relay receivers have eight wires emerging from the unit, identified by colour code. Each servo then connects to two receiver relays, as shown in Fig. 10.10. The colour code shown is widely adopted but is not necessarily the same with all makes of servos. Note that five wires go to the receiver circuit (via a plug-and-socket connection in a practical installation); whilst three to the centre-tapped battery are common to all servos in the system.



NOTE: ALL SERVOS WIRED TO COMMON BATTERY CONNECTIONS

Fig. 10.10.

This wiring provides "bang-bang" movement of the servo with self-centring on release of signal, e.g. for rudder, elevator and ailerons. For progressive action (for elevator trim and motor speed control), wiring connections to the receiver relays are merely modified as shown in Fig. 10.11.

Some multi-servos intended for working with relay receivers have spring return self-centring with mechanical limit stops, dispensing with the usual built-in switcher board. These only need two wires for connection and a single battery, with the wiring connections as shown in Fig. 10.12. The cross connections required can be done on the plug. Thus although only two wires have to be connected from the servo an 8-pin plug and socket may be used, pins 1 and 4 providing the actual servo connection to the relay and pins 5, 3, 6 and 8, and 2, 5 and 7, being connected together to complete the internal connections on the relay and battery circuit.

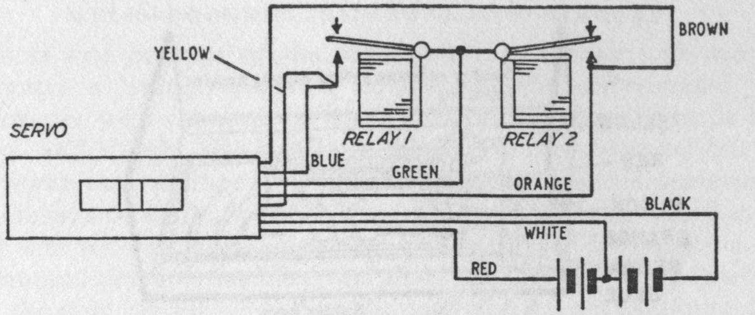


Fig. 10.11.

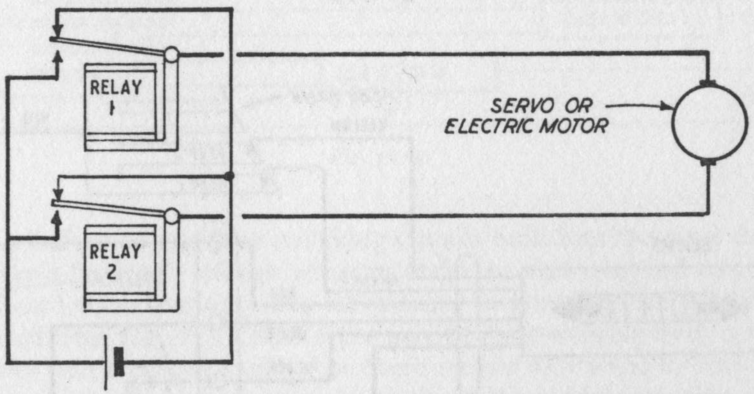


Fig. 10.12.

In the case of a relayless receiver each servo is connected directly to

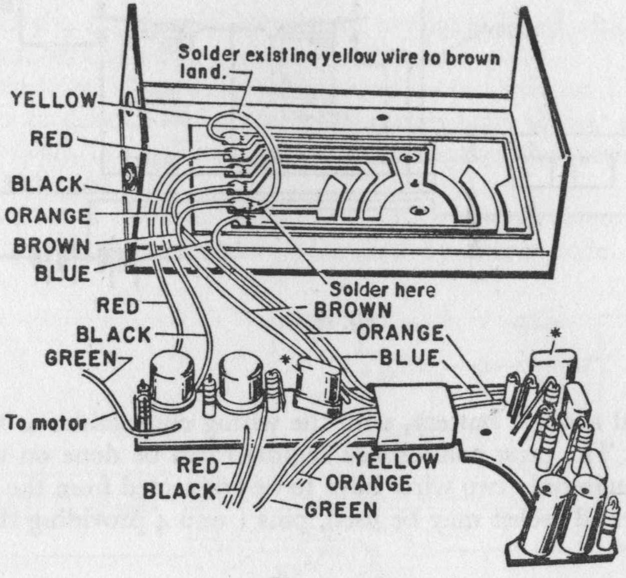


Fig. 10.13a.

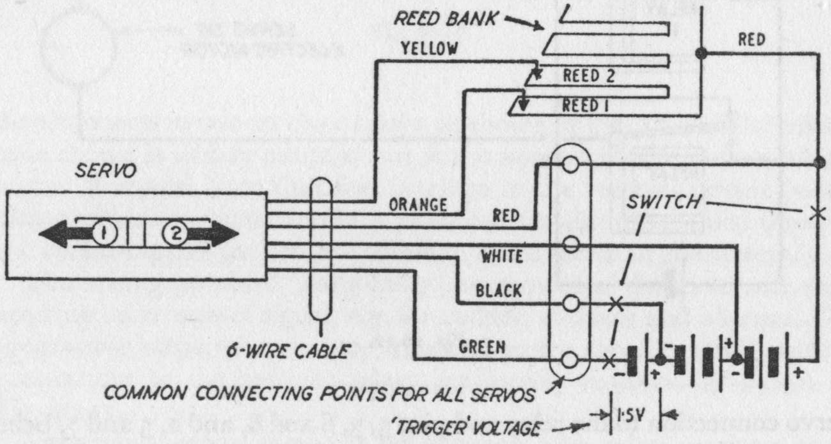


Fig. 10.13b.

a pair of reed contacts on the reed bank. The servo in this case incorporates a built-in amplifier circuit and the conventional type employs six wire connections which are completed as shown in Figs. 10.13a. and 10.13b. The battery in this case is centre-tapped but also incorporates an additional "trigger" voltage for positive operation of the transistor switching circuit. This is for normal "bang-bang" movement with self-centring. If the servo is intended for progressive action the internal circuit is modified and there are only five wires emerging from the unit. Wiring up is the same as before, except that there is no red wire (or equivalent colour) to connect to the commoned circuit.

There are other types of multi-servos for relayless receiver working.

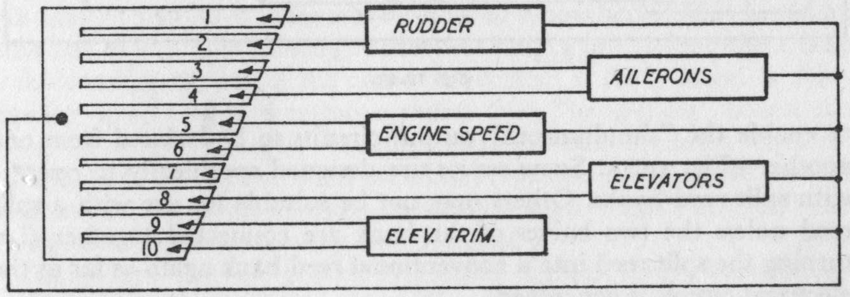


Fig. 10.14.

Some designs of transistor switching circuits built into the servo do not require a "trigger" voltage when an ordinary centre-tapped battery is used and there are only five servo wires to connect (the "green" is omitted from Fig. 13). Other types may provide working from a single battery (not centre-tapped) when there are just four wires to connect—two to the reed contacts and two to the battery, with one side of the battery also connected to the reed comb. These servos are normally produced as self-centring types. For progressive action the internal wiring is modified, but this does not affect the external connections.

Allocation of reeds for individual services is largely arbitrary except that where simultaneous signalling is provided by the transmitter, services which need to be used simultaneously should be grouped in separate simultaneous sections. With a reed bank simultaneous operation is usually limited to two groups—e.g. any one of reeds 1 to 5 can be operated simultaneously with any one of reeds 6 to 10 in a 10-reed bank. Typical allocation of reeds in such a case is shown in Fig. 10.14.

In some cases the reed bank is physically separated into two halves to enable the "simultaneous" output circuits to be isolated from one another—Fig. 10.15. Some servos are designed specifically to operate with split reed banks. Others may not be suitable for use with a split reed unless the two halves of the bank are connected together (i.e. turning the split reed into a conventional reed bank again as far as the electrical circuit is concerned).

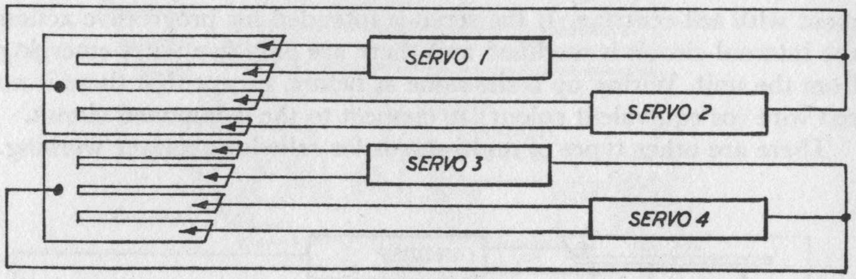


Fig. 10.15.

CHAPTER 11

MULTI-CHANNEL INSTALLATIONS—BOATS

MULTI-CHANNEL radio control for boats can utilize standard aircraft equipment as aircraft-type servos are fully capable of providing all the functional control movements required. There are, however, special boat-type multi-servos which differ mainly in providing a slower action. Thus whilst the aircraft servo has a transit time of the order of half a second or less (time from neutral to full travel), this may be increased to several seconds on a boat servo. This has some advantages as a slow-moving rudder will have a less violent effect than a fast-moving rudder, if the actual movement is fairly large. A slow-moving servo with a progressive rather than "bang-bang" action can also be used for steering by "inching" on the amount of rudder required. This form of control will work on a boat (whereas it cannot be used for a main control on an aircraft), especially when "right" or "left" can be signalled directly by using two channels.

High-speed boats are powered by diesel engines. Here "bang-bang" rudder control is required, with self-centring on release of signal; and motor speed control is an invaluable addition. Four channels will, therefore, provide complete control, using one self-neutralizing servo (for rudder) and one progressive servo (for manipulating the engine throttle).

Installation is quite straightforward. The receiver should be mounted separately in a dry part of the hull, wrapped round with foam insulation as for aircraft. Servos can be mounted directly to the hull, e.g. to a bulkhead or to the cockpit floor, and are usually best positioned aft—see Fig. 11.1a. With narrow hulls, positioning of components will have to be decided by balance requirements—Fig. 11.1b. It is essential, however, that the servos, any plug connections and the switch be shielded from engine exhaust waste or spilt fuel, as well as spray. Normally a boat engine installation should be "clean", compared with an aircraft, since the engine exhaust is normally connected to a silencer and exhaust wastes carried overboard through a length of plastic piping attached to the end of the silencer.

Electrical contacts are susceptible to attack by a moist atmosphere, particularly salt water spray. Relay contacts (where relays are used), the reeds and reed contacts and the wiping contacts on switcher boards in servos can all be affected. Thus every endeavour should be made to locate these components in compartments which will stay dry. For similar reasons all wiring should be cabled together and fastened as high as possible in the hull, rather than letting loose wiring lie in the bilges. Otherwise installation requirements follow exactly those of aircraft.

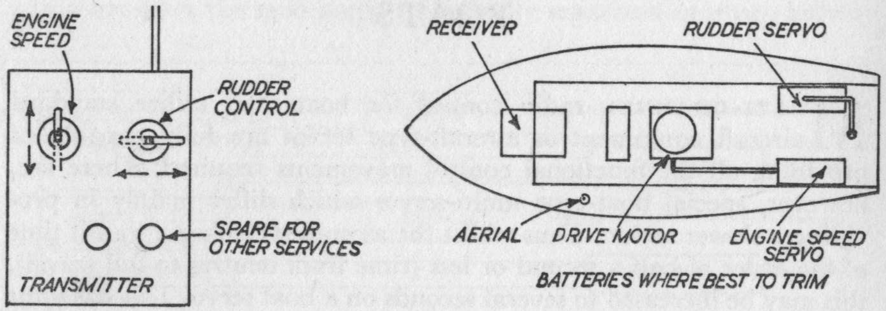


Fig. 11.1a.

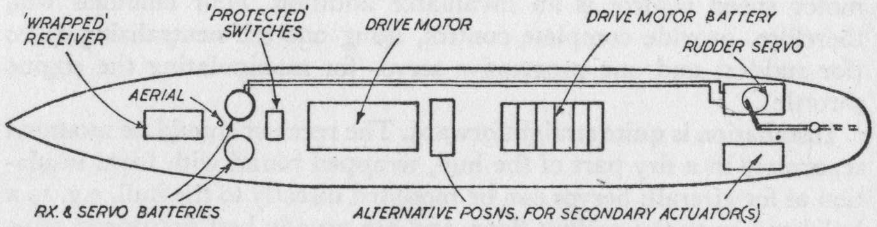


Fig. 11.1b.

As noted, the response to "bang-bang" rudder movement can be drastic and some designs of hull can become unstable if forced into a tight turn. Propeller torque may also tend to make the boat heel to one side when running, which can further affect the performance in turns. Quite often such faults can be corrected by fixed trimming devices, such as a thin wedge glued to the underside of the hull at one side to provide additional "lift"; or transom flaps which can be adjusted by bending on a trial-and-error basis to give a better trim—see Fig. 11.2. These are merely ancillary trimming devices and nothing to do with radio control as such; although movable trimming flaps controlled by a third servo with a progressive action could prove very useful on a larger and heavier boat designed for a racing performance.

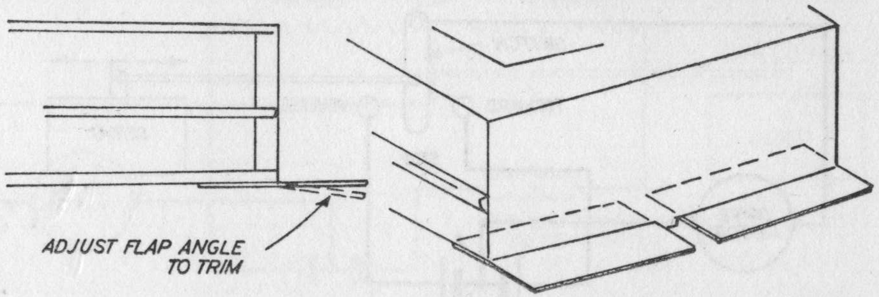


Fig. 11.2.

High-speed power boats are normally intended for racing over a specific course, or for precision steering through a series of obstacles or over a laid-out course. These cover the two main competition events. They are equally suitable for operating just for fun on any suitable pond, although in this case the control requirements are not so demanding. It is sufficient in the latter case that complete control is available via "bang-bang" rudder (for directional control) and engine speed (for slowing the boat right down when necessary).

For greater precision in control there may be a distinct advantage in providing both "bang-bang" rudder action and rudder trim control via an additional (progressive) servo. The time control can then be used for "fine" steering and the main "bang-bang" movement for rapid turns. The hook-up in this case would follow normal aircraft practice as applied to elevator and elevator trim controls operating the main pushrod via a trim bar, although the trim movement required would be rather greater than the 2 degrees common with aircraft.

It is also possible to control a fast-moving boat with a progressive rudder action, using a slow-moving actuator, and some operators prefer this type of control. It is, however, less positive in that it provides only two "positive" positions—full-left or full-right rudder—and the control setting for straight running has to be established by observed results rather than releasing the control and allowing the rudder servo to self-centre. Conventional "bang-bang" control is much easier to start with, and the violence of such a control movement can be offset by correct manipulation of the signalling key, i.e. "blipping" on control signals rather than trying to hold on full rudder every time a turn is called for.

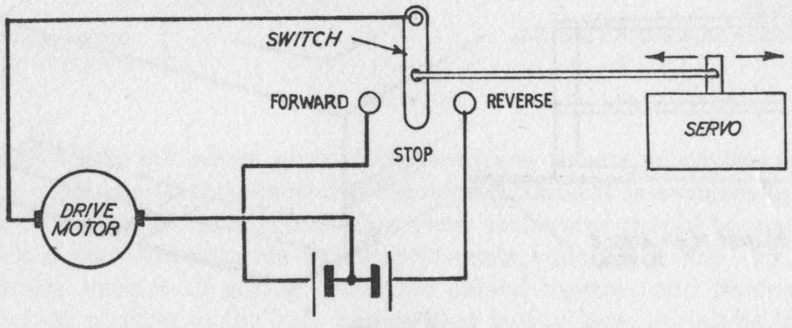


Fig. 11.3.

Normally the functional control available over a diesel-powered boat is restricted to rudder (for direction) and speed, from "slow" to maximum. It is possible to extend speed control to "stop" and even "reverse" by using a variable-pitch propeller operated over a range of pitch angles through a servo. No commercial propeller units of this type are available, however, and the design and construction of such a fitting is tricky.

With electric motor power, speed control for "forward", "stop" and "reverse" can be obtained by using a servo to drive a simple switch, wired into the motor circuit as shown in Fig. 11.3. The servo should be of the progressive type. It is then held on with the appropriate signal to drive to its limiting position and then released to select either "forward" or "reverse". "Stop" is found by "inching" the servo back until the motor circuit has been broken.

Although very simple to fit up, a better speed control is shown in Fig. 11.4. Here the progressive servo drives a potentiometer with the centre connection broken. Fully variable speed is now available by "inching" the servo in one direction or another, gradually decreasing the resistance in the motor circuit. Taking the servo to the limit of its travel gives full speed. The potentiometer must, however, be capable of carrying the full current likely to be drawn by the electric motor, which may be several amps in the case of large motors powered by accumulators.

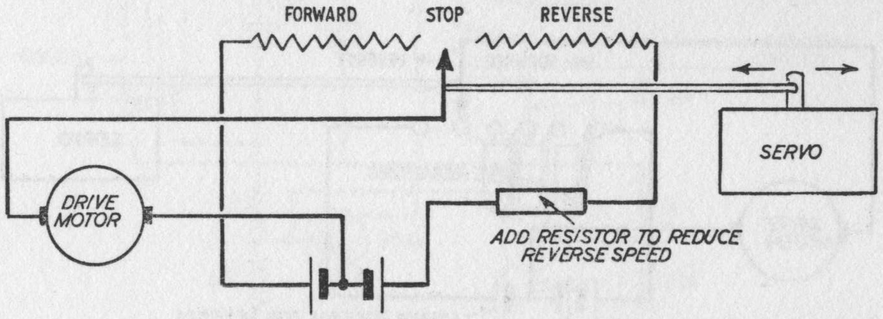


Fig. 11.4.

An alternative system which may be preferred, especially where high currents are involved in the motor circuit, is to use the servo to drive a linear switch, the individual steps on the switch being inter-connected by resistors—Fig. 11.5. This will provide a speed range selectable in steps by "inching" the servo from one (switch) position to the next.

Similar speed steps are not really required for "reverse", where one speed only is quite satisfactory for practical control. If the normal motor speed is quite high, however, it will be advisable to reduce the "reverse" speed selected by the switch, either by reducing the reversed polarity battery voltage supplied with the switch in the reverse position or incorporating a resistor in the reverse circuit to drop a proportion of the battery voltage.

Some boat-type electric motors are made with separate windings for forward and reverse running, the latter giving a lower running speed. Motors may also be fitted with a "forward-stop-reverse" switch, in which case this may be operated directly by the speed-control actuator, considerably simplifying the installation and wiring required.

As with single-channel, switching circuits for ancillary services can be electro-mechanical or electronic. The advantage offered by "multi" is that the main services can be entirely separated and directly accessible through their respective channels and the spare channels allocated for ancillary controls. Simple mechanical hook-ups are normally preferred for main controls, e.g. rudder and throttle control with diesel engines, as these offer the most straightforward manner of working.

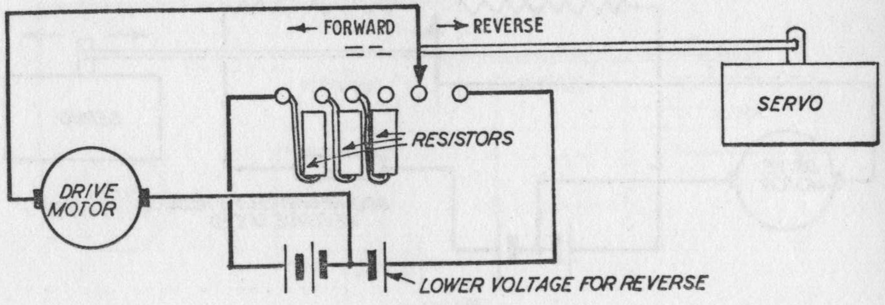


Fig. 11.5.

With electric motor main drives there may be a distinct advantage with small models in utilizing compact transistor circuits for switching. Thus Fig. 11.6 shows a simple transistor flip-flop circuit controlling a relay which acts as a simple reversing switch for the main motor, immediately latching into "forward" or "reverse" switching on receipt of an appropriate signal blip.

Flip-flop circuits of this type may be extended in many ways for "changeover" switching, operated on receipt of a signal blip. Model boats, in fact, offer an ideal ground for experimental installations of a type which, without extensive development, could not be used in air-

craft because of the possibility of malfunctioning. Loss of sequence or malfunctioning of an ancillary boat control is hardly likely to put the model or equipment in any danger, especially if such special circuits leave the main functional controls still free to be selected on the basis of conventional "multi" operation.

Since the main control functions can be covered adequately by four channels, this means that ancillary services can be worked via the remaining channels. Thus 6-channel equipment leaves two additional channels which can be utilized for two separate sequenced control circuit allocations on the lines of single-channel working; 8-channel equipment would give four separate channels for sequenced circuits; and so on. If certain ancillary services are important enough to warrant individual selection they can be allocated one or, if necessary, two channels for direct access.

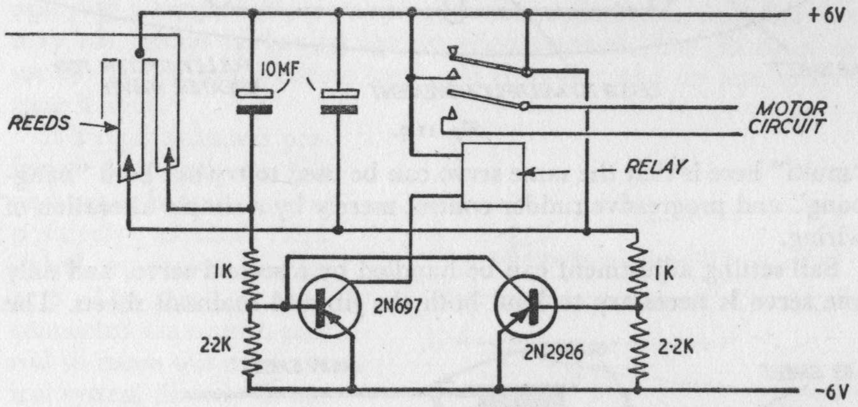


Fig. 11.6.

In the case of a yacht the rudder is still the main control, operated by a conventional multi servo, although there is a strong case here for favouring a progressive action servo rather than "bang-bang" rudder action. Either system will work. "Bang-bang" rudder action will be simpler to use, but progressive rudder control where the rudder position is trimmed and thus used continually for directional control can make for better sailing. It takes more practice to master, however, and is less suitable for dealing with sudden changes in course which the yacht may take if disturbed from its normal trim. An advantage with "multi" here is that the same servo can be used to try out both "bang-bang" and progressive rudder control merely by a simple alteration of wiring.

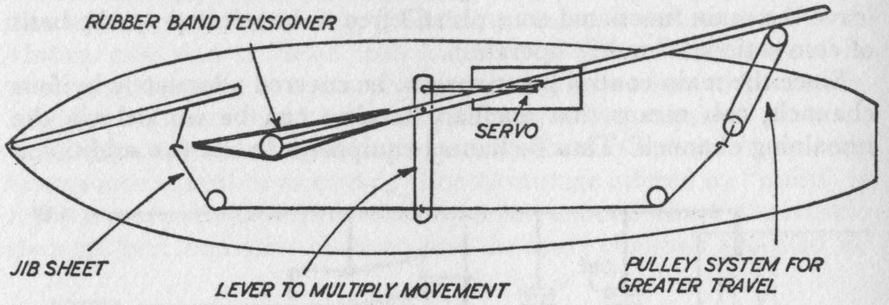


Fig. 11.7.

Sail setting adjustment can be handled by a second servo, and only one servo is necessary to haul both the jib and mainsail sheets. The difference in movements required can readily be accommodated by using a pulley system on the main sheet, which will require the greatest in-and-out movement—Fig. 11.7.

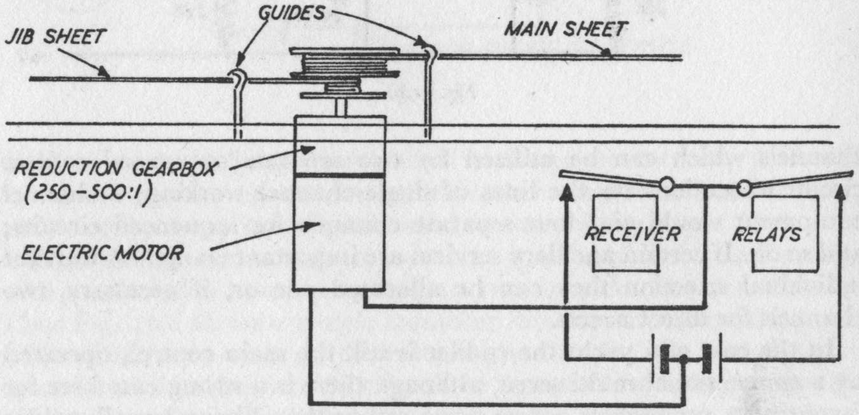


Fig. 11.8.

With a conventional servo the pull can be taken directly from the servo output, or from a bellcrank linked to the servo output, as most convenient. An alternative method is to use a geared-down motor fitted with a drum to act as a winch in place of the servo, but in this case simple connection is then possible only with a relay-type receiver wired as shown in Fig. 11.8.

Sheet hauling systems will inevitably involve handling a considerable length of flexible line and consistent operation for hauling in depends on the line being in tension. This provision can usually be met by applying a simple off-centre spring to the main boom since the sheet may not always be hauled against wind pressure. The jib sheet can usually be left to look after itself as it is shorter and far less liable to snag if slack.

If a rigid system is preferred then both the jib and main booms can be positively pivoted and linked, as shown in Fig. 11.9. The servo is then connected via a push-pull rod to move this mechanical system directly in the manner of an aircraft control. Mechanically, this is a much better system, although clumsy in appearance.

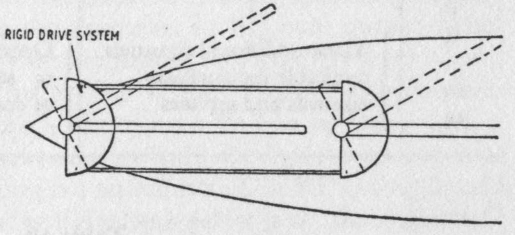


Fig. 11.9.

As with power boats there are many secondary controls which can be added to improve realism of operation, but as a general rule these should always be controlled by separate channels so that the main controls are directly accessible. In other words, in planning a radio control system for any boat, ensure that the main functional controls are covered first and group the other controls, as necessary, for operation via the remaining channels—see Tables 17 and 18.

How this is done is largely a matter of cost. Thus *any* additional control or service will be easiest to operate if it is commanded by two separate channels and driven by a multi-servo, but this will substantially increase the cost of the equipment. To economize, spare channels can be used singly to operate individual services through single-channel actuators; or several controls operated in sequence off a single-channel via a switcher, as in normal single-channel working for boats.

Table 17

CHANNEL ALLOCATIONS FOR POWER BOATS

No. of channels	*Channels*	*Control*	*Remarks*
2	1 and 2	Rudder	"Bang-bang", S/N or progressive
3	3	Motor speed	Changeover—high-low-high etc. (diesel) Sequence switching (electric)
4	3 and 4	Motor speed	Progressive throttle (diesel) or Sequence switching (electric)
6 8 10 12	These additional channels available for ancillary controls and services		Operated via single-channel actuators or sequence switches for multiplicity of controls

Table 18

CHANNEL ALLOCATIONS FOR YACHTS

No. of channels	*Channels*	*Control*	*Remarks*
2	1 and 2	Rudder	Progressive or "Bang-bang" S/N
4	3 and 4	Sail setting	Hauling jib and main sheets via winch or direct push-pull output and lever system
6	5 and 6	Rudder trim	Used with "bang-bang" main rudder movement
8 10 12	Additional channels for ancillary services if required		

CHAPTER 12

MULTI-CHANNEL OPERATION

THE conventional multi-channel transmitter is provided with potentiometers for adjusting the individual tones, these normally being accessible by removing the back of the unit. This is to enable the tones to be tuned to match the resonant frequencies of the individual reeds in the reed bank. Provision is also made for adjusting the transmitter RF (radio frequency) output or carrier signal strength. This is normally pre-set for maximum RF output at the factory and needs no attention on the part of the user. However, some transmitters may specify adjustment of RF as a requirement. In this case output signal strength is usually indicated by the brightness of a small indicator lamp or the reading on a built-in meter. RF output tuning then involves adjusting the trimmer control(s)—there may be one or two—with a tuning wand or non-metallic screwdriver until the indicator lamp is at its brightest, or the meter reading is a maximum. This RF tuning should be done with a signal keyed on; or if the transmitter is of "simultaneous" type, with a signal keyed on in each "simultaneous" bank.

A further useful check if RF output tuning is required, or attempted, is to connect a milliammeter temporarily into one battery lead. This will provide an indication of over-tuning. As the tuning point for maximum RF output is reached, the current drain, as indicated by the milliammeter, will rise quite appreciably. Having reached the setting for peak RF output it is possible to "overtune" which will not result in any increase in RF output but will go on increasing the current drain unnecessarily. The meter enables adjustment to be backed off from an "overtuned" position without losing RF output.

Before attempting to tune the potentiometer (tone) controls the receiver must first be tuned to the transmitter, unless it is a superhet. type when it will be pre-tuned. This follows a similar procedure to that described for single-channel operation, except that it is not necessary for the servo circuits to be connected. Response is best judged, for initial tuning at least, by opening the case of the receiver and observing the reaction of the reeds.

With the receiver and transmitter at close range, switch on both circuits and operate one of the transmitter signal keys. One of the reeds on the reed bank should start to vibrate or "drive". If not, adjust the tuning control on the receiver until one does. The tuning control is then adjusted first one way and then the other until the reed stops vibrating, finally setting the tuning adjustment back to the middle position—Fig. 12.1. This is exactly like finding the optimum tuning position with a single-channel receiver.

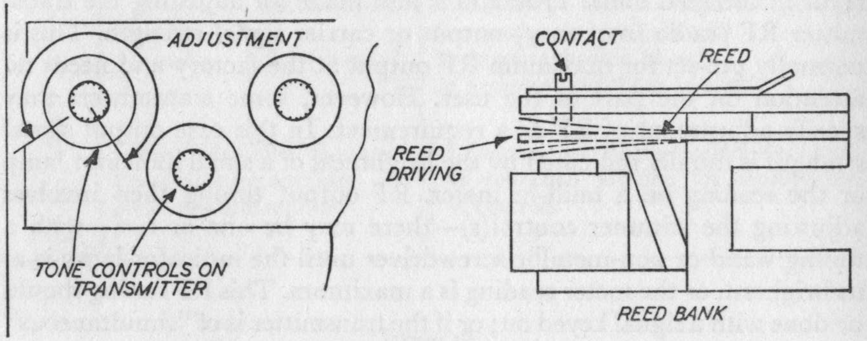


Fig. 12.1.

There is the possibility that no reed will start to drive even over the full range of tuning adjustment. In that case the tuning control should be set back to its original position and the tone control on the transmitter associated with the key being used adjusted until one reed does pick up. Then proceed as above to find the optimum tuning point for the receiver.

If adjusting the transmitter tone control still does not work, and there are no obvious circuit faults such as a disconnection, then probably the reed bank is not matched to the range of tones generated by the transmitter. In that case either the reed bank will have to be changed for a matching type, or component values changed in the transmitter tone circuits to cover the reed-bank tone range. The latter is by far the cheapest solution, but does demand practical knowledge of radio control circuitry to attempt.

With receiver tuning established, the transmitter tones can now be adjusted for best performance. Each transmitter key will normally command two tones, one in each of its extreme or signalling positions. Each tone is controlled by its own potentiometer; and each tone should cause one reed only to drive. For this stage of adjustment the servo circuits must be disconnected from the receiver as there is the possibility that adjacent reeds may be driven simultaneously, which could cause a short on the corresponding servo circuit output.

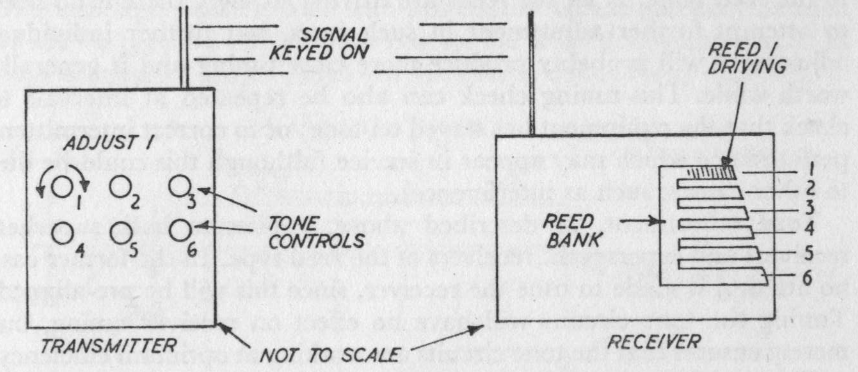


Fig. 12.2.

Each tone is now individually tuned in turn. The key is pressed to start the appropriate reed driving and, with signal held on, the corresponding potentiometer (tone control) on the transmitter is adjusted for maximum drive, i.e. for the point at which the reed vibrates most strongly—Fig. 12.2. Check that this strong drive is picked up each time the key is operated. It does not always follow that the potentiometer setting which gives the strongest drive when the signal is held on continuously will give the strongest drive with intermittent keying.

This operation is repeated for each tone in turn. With a "simultaneous" transmitter, work alternately from one tone in one of the simultaneous groups to another tone in the second simultaneous group.

Having adjusted with a continuous signal, check that the reed drives properly when signals are keyed simultaneously on both groups, i.e. key two tones simultaneously for final adjustment of the second tone potentiometer. Work right through the individual tones in this manner. You should then have the transmitter and receiver set up for optimum working.

It then remains to check out receiver tuning again with a range check, as described in Chapter 8; and finally that all the control services work with the engine running.

In many cases, especially with new equipment, the transmitter and receiver will be pre-tuned, and with the tone circuits properly adjusted to the reed bank. If all the reeds are driving strongly there is no need to attempt further adjustment in such cases, but further individual adjustment will probably produce more close tuning and is generally worth while. This tuning check can also be repeated at intervals to check that the equipment has stayed on tone; or to correct intermittent performance which may appear in service (although this could be due to other causes, such as interference).

Tone adjustment, as described above, applies to both superhet. receivers and superregen. receivers of the reed type. In the former case no attempt is made to tune the receiver, since this will be pre-aligned. Tuning the tone circuits will have no effect on receiver tuning, but merely ensures that the tone circuits are working at optimum efficiency.

The reed bank itself should normally need no adjustment, unless it has been incorrectly set up initially or the contacts have been displaced in a crash. If adjustment does appear necessary then the following points should be observed.

As a general rule all the reeds should be in line (i.e. in the same horizontal plane) and with approximately $\frac{3}{64}''$ clearance between the reeds and the pole piece beneath them. The reed contacts should be positioned so that when driving the reed has about $\frac{1}{16}''$ movement at the tip for the shortest reeds, increasing to about $\frac{5}{64}''$ movement at the tip on the longest reed—Fig. 12.3.

If the reed drive is poor this may be due to low batteries, low transmitter power (which again can be low batteries), incorrect tuning of the transmitter tone control, or too great a clearance between the reed and the pole piece of the coil. Suspect these causes in that order.

Clearance should not normally be adjusted unless it is pretty certainly the cause of the trouble and decreasing the reed clearance will tend to make it more likely to vibrate in sympathy when an adjacent reed starts driving. Some interaction of this nature may be inevitable on certain reeds, but this can be accepted as normal if the adjacent reed does only tremble and not vibrate strongly enough to touch its contact.

Operation of "multi" controls is quite straightforward. With a "bang-bang" servo holding on a signal will hold on full control position. This will produce a violent response from an aircraft rudder control, so rudder control is usually signalled with "blips" rather than a held-on signal. The same with elevator control used for controlling a climb or dive, although with elevator trim this control would normally be used for such a purpose and elevator control for main manoeuvres, such as loops or inverted loops. Turns via the aileron control may also need to be "blipped", or held on, according to the movement available and the power of these controls. Thus powerful ailerons held on will tend to produce a roll rather than a banked turn.

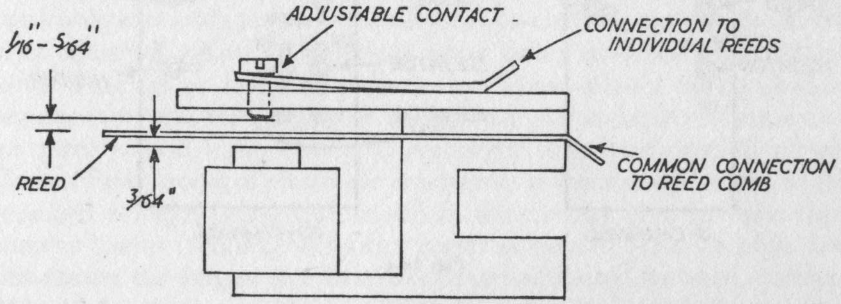

1/16" - 5/64"
ADJUSTABLE CONTACT
CONNECTION TO INDIVIDUAL REEDS
REED
3/64"
COMMON CONNECTION TO REED COMB

Fig. 12.3.

The trim controls are "inched" on or off. The key is simply operated in a series of blips to establish an intermediate position, or held on when full movement is required, remembering that the control will stay in the last position when the signal is released.

Basically, "bang-bang" controls provide an uneven form of control, especially for aircraft, as the effect of "intermediate" control positions can only be achieved by "blipping" the control. Hence the model will tend to "hunt" between the two extreme conditions (control on and control off) rather than respond smoothly. However, with practice the response can be quite smooth, although not as smooth as can be achieved with true proportional controls.

The smoothest control and thus the most effective control (as well as being the most pleasing to watch) comes from operating all the signal keys by "blipping". This means that, effectively, a "proportional" control action is produced, governed by the rate of "blipping" and the skill of the operator in applying the blipped signals correctly. It is also important to allocate the transmitter keys for logical control operation, so that the keys move in the same direction as the control movement and are logically grouped for easy manipulation—see Fig. 12.4.

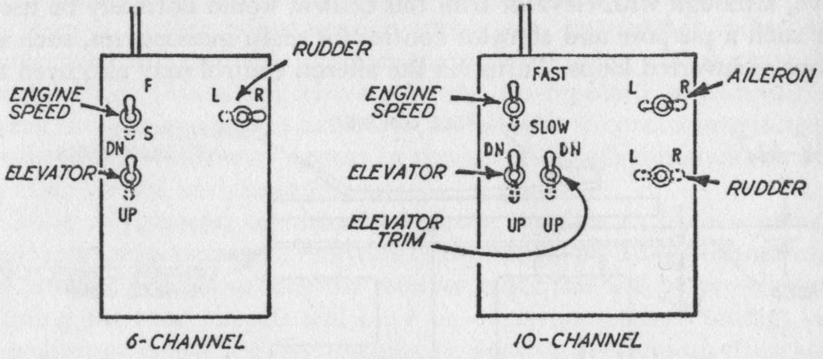


Fig. 12.4.

Just how well an aircraft model behaves with conventional "multi" controls is also a matter of model design and trim. A suitable design can be trimmed "zeroed out", that is, with neutral stability. If then, say, elevator control is applied momentarily to change its flight attitude and the control then returned to neutral the model will continue to follow its new flight attitude and not recover to its original position. Thus trim is a vital part of getting really successful and basically smooth performance.

Trim should also aim at ensuring that the model flies straight and level with neutral elevators and neutral elevator trim. Straight flight can be adjusted by offsetting the thrust line to the right, as necessary, to counteract torque. This will only be successful if the model is rigged correctly and is free from warps or misalignment of the flying surfaces.

Level flight can be achieved by adjusting the balance point and, if necessary, the incidence of the wing and tailplane. Trim by tailplane adjustment, if used, should also adjust the elevator setting so that this is still lined up with the tailplane in the neutral position.

Trim controls, when available, can of course compensate for deviations in model trim. This is of considerable help for the initial flights when elevator trim, for example, can correct an under- or over-elevation of model trim which might otherwise prove disastrous. Similarly rudder (or aileron) trim control could correct for improper alignment. What are essentially model rigging or balance faults, however, should always be trimmed out in conventional free-flight model fashion as this will make the model both safer and easier to fly, and make the trim controls more effective as controls, which can then be used to achieve maximum performance from the model.

Using modern commercial units, equipment faults should be comparatively rare with properly installed single-channel systems. By far the most common source of trouble is weak batteries—receiver batteries, servo batteries or transmitter batteries. These should be checked at regular intervals. Rechargeable DEACs are particularly recommended for receiver and servo batteries, recharged after each session of use. Correct functioning of electronic equipment is strictly dependent on the required voltages being maintained in the circuits; and in some cases current drains (tending to flatten batteries quickly) can be high. For this reason the largest size batteries practical should be used, particularly where there may be four, five or even six motorized servos all powered by a single servo battery.

Boat installations are usually better off in this respect, for battery size and weight is seldom critical and so larger batteries can be used to provide a generous reserve of capacity. Again, however, the transmitter batteries are usually restricted in size to a standard type selected to fit inside the case and the possibility of these running down during use should always be borne in mind. With an output indicator on the transmitter RF circuit, a falling battery voltage will be shown by the indicator lamp glowing less brightly, or the meter reading falling.

Table 19

FAULT-FINDING CHART—MULTI-CHANNEL EQUIPMENT

Fault	*Cause*	*Remarks*
Does not respond to transmitter signal	Reeds not responding	Check tuning of reeds, as described. If no reed will respond, check tuning of receiver. See also faults under single-channel receivers (Chapter 8)
Reeds drive but servos do not work	Reed contact adjustment	Check and readjust if necessary
	Faulty component	Check output circuit from reed bank
	Dirty contacts	Check reed bank contacts for corrosion or burning; check servo switching board and contacts.
	Relay contacts (relay receivers only)	Check relay for correct response to reed operation Check and clean relay contacts
	Weak batteries	Check servo battery voltage under load
	Servo motor fault	Check that commutator is not dirty and that brushes are in good condition and making proper contact
Two servos work when one is signalled	Tone adjustment	Readjust tone pots. on transmitter to try to isolate reed response.
	Interference	Check that servo motors are fully suppressed *Note:* interference may be from an outside source, e.g. another transmitter
Simultaneous servo response is weak	Weak batteries	Check battery condition. Batteries may be of insufficient voltage initially
	Initial adjustment	Re-check tone adjustment with tones keyed simultaneously
Inconsistent operation	Vibration	Insulate receiver from vibration; mount with reed comb vertical

Table 19—continued

Fault	*Cause*	*Remarks*
		Check that vibration has not loosened servo parts, such as holding screws
	Dirty contacts	Check servo switching boards and wiper contacts
Lack of range	Weak batteries	Check voltage under load
	Weak transmitter signal	Check transmitter batteries Check that aerial is fully extended
	Incorrect tuning	Check tuning of receiver to transmitter
	Weak batteries	Check receiver batteries under load
Spurious signals received and responded to	Interference	Probably from an outside source; cannot be eliminated, except by using a superhet. receiver, which is far less likely to be subject to interference
	Circuit instability	Faulty component or intermittent connection in receiver circuit, check that servo motors are properly suppressed
Loss of control (all channels)	Weak batteries	Always check battery voltages regularly under load and replace (or recharge) regularly
	Inadequate range	A range check is essential to establish final tuning; repeat as a check at regular intervals
	Circuit fault	Most likely cause is a disconnection caused by vibration—e.g. a wire falling off or a plug separating from a socket
Loss of control (two channels)	Reed fault	Burnt reed caused by passing too heavy a current
	Tone drift	Loss of stability on transmitter tone circuit
		Unsatisfactory reed bank producing resonant frequency drift due to fatigue

CHAPTER 13

MULTI-PROPORTIONAL CONTROLS

A TRUE proportional control movement produces a steady control position displaced from neutral by an amount exactly proportional to the signal change—e.g. proportional to the actual mark: space ratio where varying mark: space ratio is used as the signal. In practice the actual position of the control may be modified by "blowback", as mentioned in Chapter 9. This can be overcome by connecting the servo in a closed-loop circuit incorporating an element for detecting any difference between control position and the position signalled and feeding any difference back in the form of an "error signal"—Fig. 13.1. This "error signal" then applies correction, as necessary, to continue driving the servo to its correct proportional position.

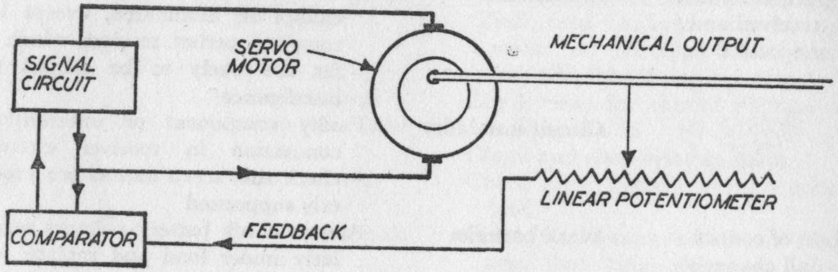


Fig. 13.1.

In practice the detecting element is usually a potentiometer driven by the servo output. On receipt of a "proportional" signal the servo motor will then drive until balancing conditions are reached, i.e. there is no error signal remaining in the closed-loop circuit. It will then stop in this position, which will be a movement directly proportional to the movement of the control initiating the original signal, e.g. a control stick on the transmitter.

Apart from the addition of a potentiometer the mechanical side of the servo is similar to that of a conventional multi servo—see Fig. 13.2.

The electrical circuit is, however, considerably more complex as modern units of this type normally incorporate built-in fully transistorized switching circuits to deal with the signals decoded in the appropriate section of the receiver. The receiver circuit is also of special design, according to the system employed, and specifically matched to the transmitter. The combination may then provide two, three, four or more independent and fully proportional channels, each of which then controls its own proportional actuator.

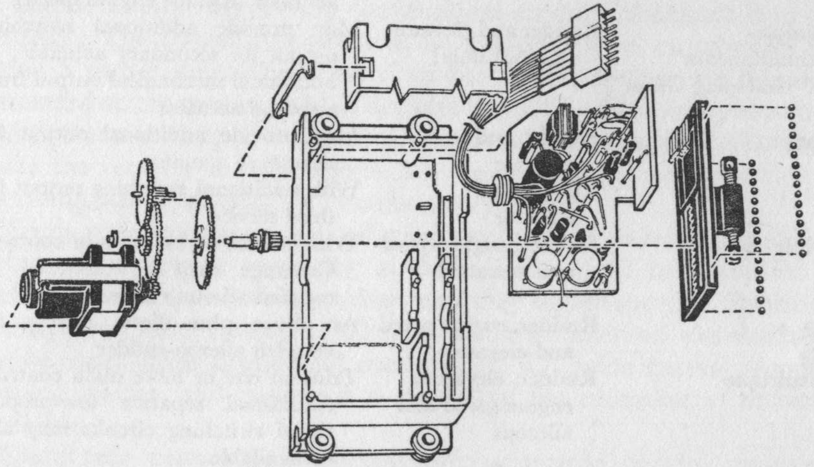


Fig. 13.2.

Circuits of this type have been a fruitful field for experimental development for electronics experts for many years, but it is only recently that successful commercial equipment of this type has appeared. These are invariably fully pre-tuned units which need no adjustment, and are also usually ready-wired for plug-together assembly of receiver, servos and batteries. They are, therefore, eminently suitable for use by any modeller and require no electronic knowledge at all to install and operate. They are, however, extremely expensive and costs increase directly with the number of proportional channels available.

Proportional equipment is normally referred to as either "analog" or "digital" type. An analog system responds with infinite variations

Table 20

BASIC CLASSIFICATION OF PROPORTIONAL CONTROLS

Type or Description	*Proportional control(s)*	*Other control(s) available*
Single	Rudder	May provide an additional switching output operated by "pulse omitted" signal for operating a secondary actuator (e.g. for engine speed)
"Simple-simultaneous" ("Galloping Ghost")	Rudder and elevator (aircraft only)	May provide additional switching output for secondary actuator; or additional mechanical output from a special actuator
Dual	Rudder and elevator	May provide additional output for secondary actuator
2 + 1	Rudder and elevator	With additional switching output for third service
Triple	Rudder, engine speed and elevators	Trim on one or more main controls. Coverage may be extended by coupled aileron-rudder
3 + 1	Rudder, engine speed and elevators	As above plus direct facility for coupled aileron-rudder
Quadruple	Rudder, elevators, engine speed and ailerons	Trim on one or more main controls. Additional separate low-proportional switching circuits may also be available

Note: More elaborate circuits may provide five, six or more fully proportional controls, with or without additional switching circuits for non-proportional controls.

to a change in signal, rather in the manner in which a milliammeter would respond to a change in current flowing through a circuit in response to movement of a potentiometer in that circuit. A digital system on the other hand produces a proportional response by "counting" pulses or similar signal logic. In this respect it can be more exact than an analog system, although the circuitry involved is usually more complicated.

Two-channel proportional or dual-proportional provides the simplest system when the individual proportional circuits can be controlled by variable pulse-rate and variable pulse-width, respectively. This would provide adequate functional control coverage for boats, but limits aircraft control coverage to rudder and elevator. However, it is readily possible to add a third simple control service operated by conventional single-channel type switching, e.g. by a momentary interruption of the carrier signal, which could be used for motor speed changeover. Also there is always the possibility of using coupled aileron and rudder further to extend the control coverage available.

Dual-proportional systems of this type can be used with standard receivers (normally relay-type only) feeding into a decoder unit with an output suitable for driving conventional servos (if feedback is to be omitted). The transmitter needs to be a special type, or adapted by fitting a pulser unit. The "brain" of the system is then the decoder connected to the receiver which decodes the pulse-width and pulse-rate signals electronically in terms of proportional output signals. Alternatively the receiver may be specifically designed for dual-proportional operation with the decoding circuits incorporated.

Triple proportional systems offer full proportional control of rudder, elevator and engine speed for aircraft. This would normally be a preferable arrangement rather than omitting engine speed in favour of ailerons; or rudder instead of ailerons (although ailerons, elevator and engine speed form a practical combination for pylon racers). Again, coupled aileron and rudder is a possibility for extension of services available.

Quadruple proportional systems offer complete control coverage for aircraft—rudder, elevators, engine speed and ailerons and it is not necessary to go beyond that for functional control coverage. Many systems from dual proportional up do, however, incorporate additional control channels which may be used for other services. These may be progressive-type controls operated on two channels in the manner of conventional "multi"; or single-channel controls.

Each proportional control is, in effect, the equivalent of two channels of conventional "multi" as far as control allocation is concerned, but it does, in fact, provide more than this. A trim control can readily be incorporated as an addition (operated by a separate lever), and it would need two further channels of conventional "multi" to provide this extra service on the same control. There are no exact equivalents although Table 21 outlines a broad basis for comparison.

Table 21

APPROXIMATE PROPORTIONAL EQUIVALENTS

(Aircraft controls)

Proportional type	*Equivalent to "multi" coverage by:*
Single	2-channel (rudder)
Dual (with extra service) or 2 + 1	6-channel
2 + 1 with coupled-aileron-rudder	8-channel
Triple	8-channel
3 + 1 with coupled-aileron-rudder	10-channel
Quadruple	12-channel

Control manipulation is normally by stick at the transmitter end for main controls, the stick or sticks being spring biased to centre. Thus a control surface will self-centre when the control stick is released since this adjusts the signal to correspond to "neutral" position. Allocation of controls is largely arbitrary. Thus rudder and elevators may be commanded by a single stick with ailerons controlled by a separate stick; elevator and ailerons by a single stick and rudder by another stick, and so on. Trim for these main controls would then normally be available through a lever movement. Throttle control may be by two pushbuttons or a lever movement. In some cases throttle trim may also be provided by a separate lever. With proportional or progressive throttle movement already available, this would seem an unnecessary addition, but in such cases could be used to select a limit position (usually maximum throttle) for operating an additional service, in a similar manner to the use of extreme throttle position to uncouple a coupled-aileron-rudder system (see Chapter 10).

Since proportional controls provide infinite adjustment of a control position between neutral and full on, the degree of control available is much greater than with conventional "multi" and "bang-bang" servo operation. The great advantage is that much smoother control can be maintained, because only the amount of control necessary can be selected. At the same time it obviously needs more practice to use proportional controls efficiently since, in effect, the model is being controlled all the time; whereas "bang-bang" controls are basically used to displace a model from its original position or attitude. There is thus a tendency to over-control and over-correct initially when using proportional controls.

In practice the changeover from using "bang-bang" to proportional controls is quite straightforward. The proportional system can be operated like "bang-bang" controls, i.e. using full control movements only until proficiency is gained in using the controls proportionally (for intermediate control positions). Thus anyone with previous experience of conventional "multi" will have no trouble in adapting his reactions to true proportional control; although the beginner would normally find it easier to master "bang-bang" controls than proportional, starting from scratch in each case.

The fact that the control positions on a proportional system are entirely dependent on the conditions established by the radio signals all the time does have certain limitations. It makes the system particularly susceptible to interference, for instance; or to circuit failure. The latter is usually guarded against by incorporating a "fail-safe" mode in the circuit design. That is, in the event of circuit failure, all the main controls automatically revert to the neutral position. "Fail-safe" may also apply if interference occurs to upset the normal working of the system, although this can have the disadvantage that momentary interference which is repeated can cause repeated loss of control.

Rather than rely on "fail-safe" characteristics to deal with interference it is generally better if the circuit can be designed with a high resistance to interference; or the transmitter power can be increased to a level where interference is less significant and can be overridden. Some systems, in fact, rely on this implicitly and do not incorporate "fail-safe" characteristics at all. This does have the advantage of simplifying the receiver design.

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